Instruction Report ITL-96-1
June 1996

US Army Corps
of Engineers
Waterways Experiment
Station

Computer-Aided Structural Engineering (CASE) Project

User's Guide: Computer Program for Two-Dimensional Dynamic Analysis of U-Frame or W-Frame Structures (CDWFRM)

by William P. Dawkins

Approved For Public Release; Distribution Is Unlimited

Prepared for Headquarters, U.S. Army Corps of Engineers

DISCLAIMER NOTICE

THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

Computer-Aided Structural
Engineering (CASE) Project

Instruction Report ITL-96-1
June 1996

User's Guide: Computer Program for Two-Dimensional Dynamic Analysis of U-Frame or W-Frame Structures (CDWFRM)

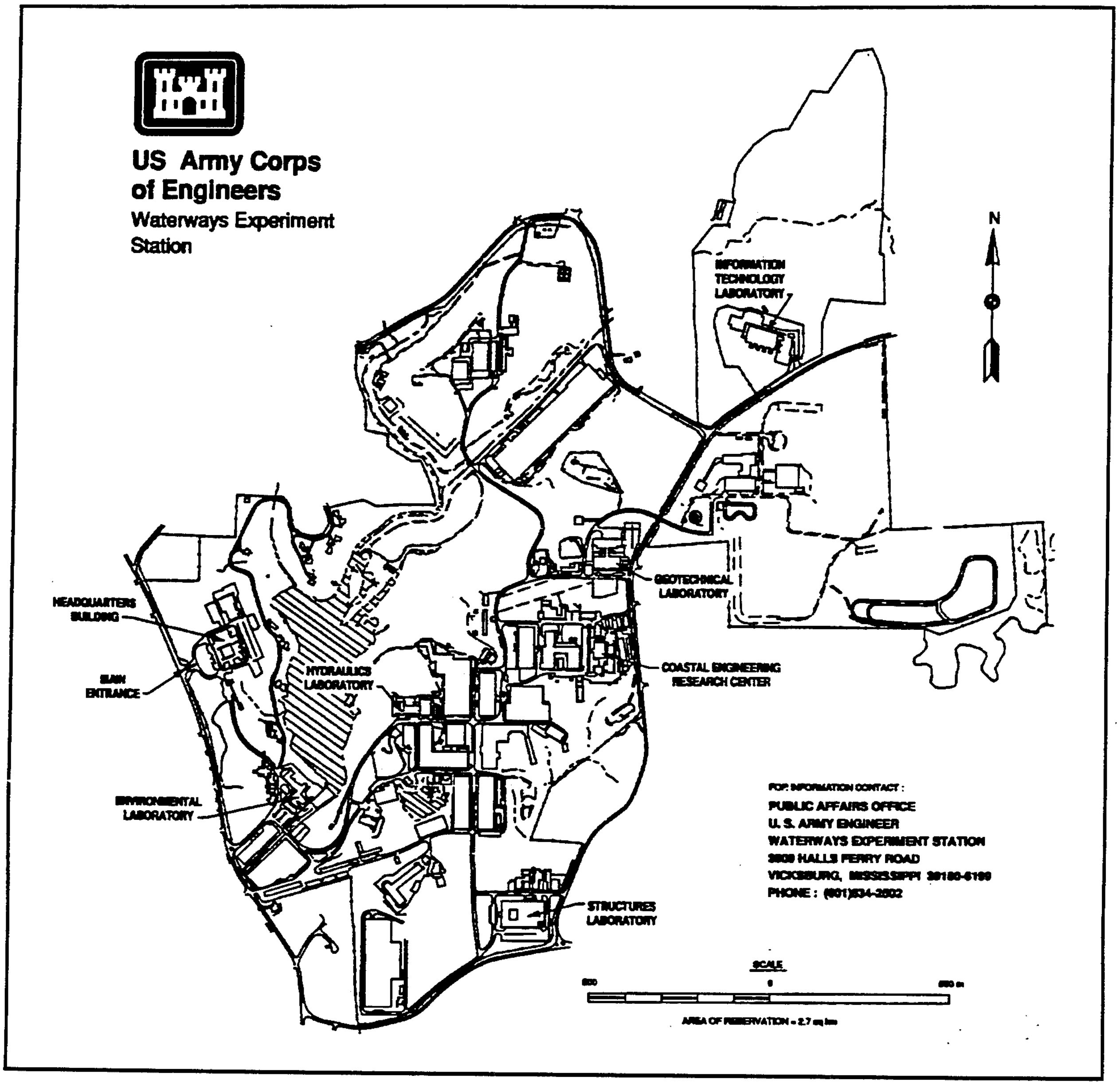
by William P. Dawkins

U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Final report

Approved for public release; distribution is unlimited

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000



Waterways Experiment Station Cataloging-in-Publication Data

Dawkins, William P.

User's guide : computer program for two-dimensional dynamic analysis of U-frame or W-frame structures (CDWFRM) / by William P. Dawkins ; prepared for U.S. Army Corps of Engineers.

110 p. : ill. ; 28 cm. — (Instruction report ; ITL-96-1)

Includes bibliographic references.

1. CDWFRM (Computer program) — Handbooks, manuals, etc. 2. Structural frames —Computer program. 3. Structural analysis (Engineering) — Computer programs. I. United States. Army. Corps of Engineers. II. U.S. Army Engineer Waterways Experiment Station. III. Information Technology Laboratory (U.S. Army Engineer Waterways Experiment Station) IV. Computer-aided Structural Engineering Project. V. Title. VI. Title: Computer program for two-dimensional dynamic analysis of U-frame or W-frame structures (CDWFRM) VII. Series: Instruction report (U.S. Army Engineer Waterways Experiment Station) ; ITL-96-1.

TA7 W34i no.ITL-96-1

Contents

Preface

This user's guide describes the computer program CDWFRM which can be used for dynamic analysis of pile supported U-Frame or W-Frame structures. The work in writing the computer program and user's guide was accomplished with funds provided to the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, by Headquarters, U.S. Army Corps of Engineers, Civil Works Directorate, under the Structural Engineering Research Program work unit of the Computer-Aided Structural Engineering (CASE) project.

The program and user's guide were written by Dr. William P. Dawkins, P.E., Oklahoma State University, under IPA agreement No. 93-15-M with WES.

The work was managed, coordinated, and monitored in the Information Technology Laboratory (ITL), WES, by Mr. H. Wayne Jones, Acting Chief, Computer-Aided Engineering Division (CAED), and CASE Project Manager. Mr. Barry Fehl is Acting Chief, Scientific and Engineering Applications Center. Dr. N. Radhakrishnan is Director, ITL.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
kips (force)	4448.22	Newtons
pounds (force)	4.4482	Newtons
pounds (force) per square inch	6894.76	Pascals
pounds (force) per square foot	47.8803	Pascals
slugs	0.4536	kilograms

1 Introduction

Description of Program

This user's guide describes a computer program "CDWFRM" for dynamic analysis of a two-dimensional (2-D) slice of a U-frame or W-frame structure. "CDWFRM" is a companion to the program "CWFRAM"[1] for static analysis of these structures and relies heavily on the documentation for that program. The program functions in the "frame analysis" mode described by Jordan and Dawkins.[1] In the frame analysis mode, a 2-D plane frame model of a pile supported monolithic concrete structure is formulated. The effects of soil and/or water in the model of the system must be explicitly provided by the user with the "additional weight" facility described subsequently. Displacements and internal forces throughout the structure, including pile forces, induced by an earthquake excitation are determined from a linearly elastic modal analysis. This program provides information regarding the response of the structure only, performs no design functions, nor does it attempt to judge the quality of the structural performance.

Report Organization

This report is divided into the following parts:

a. Chapter 2: Describes the 2-D structure.

b. Chapter 3: Describes the 2-D model formulated for frame analysis.

c. Chapter 4: Describes the methods utilized in performing the dynamic analysis.

d. Chapter 5: Describes the computer program.

---

[1] T. D. Jordan and W. P. Dawkins. (1990). "User's guide: Computer program for two-dimensional analysis of U-frame or W-frame structures (CWFRAM)," Instruction Report ITL-90-6, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

e. Chapter 6: Presents an example solution obtained with the program.

Disclaimer

This program was developed using criteria furnished by the Computer-Aided Structural Engineering (CASE) task group on W-frame structures. The procedures and philosophy embodied in the program do not necessarily represent the views of the author.

The program has been checked within reasonable limits to ensure that the results are accurate for the assumptions and limitations of the procedures employed. In all cases, it is the responsibility of the user to judge the validity of the results. The author assumes no responsibility for the design or the performance of any structure based on the results of the program.

2 Structure

System Description

The U-frame or W-frame system is a three-dimensional (3-D) U-shaped or W-shaped structure, usually concrete, surrounded by soil backfill, founded on subsoil or piles, and subjected to a variety of soil and water (both internal and external) loads. Although an accurate assessment of the behavior of the system can be obtained from a general 3-D analysis only, such an analysis is clearly prohibitive, particularly during an iterative design process.

Under the following conditions, an analysis of a 2-D slice can provide relatively reliable indications of the behavior of the 3-D system:

a. When the longitudinal dimension of the system is substantially larger than the width and height of the cross section.

b. When the cross-sectional geometry of the structure, the soil and water conditions, support conditions, and other loading effects are relatively constant throughout an extended length of the system.

c. When a 2-D slice of the system, obtained by passing parallel planes perpendicular to the longitudinal axis of the system, is representative of the adjacent slices and is sufficiently remote from any discontinuities in the geometry and loading (i.e., the slice is in a state of plane strain).

The remainder of this report is based on the assumption that the conditions presented in the previous paragraph exist in the 2-D representation.

Typical Cross Sections

The geometry of a cross section (monolith) is usually dictated by its position in the 3-D structure. Although name identifiers are frequently assigned to the various shapes, the basic types (based on the configuration of the outside stems) shown in Figure 1 will be designated as follows:

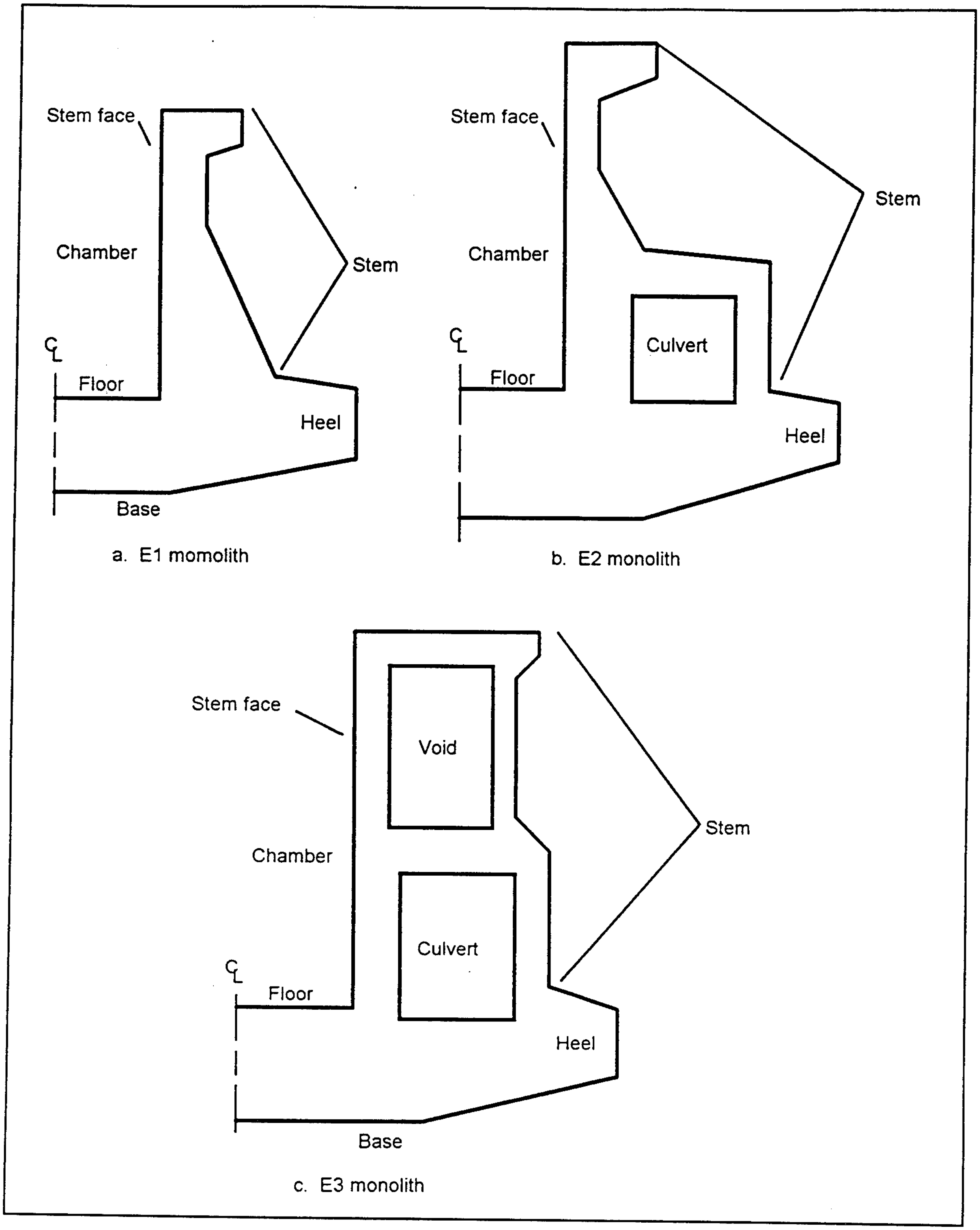


Figure 1. Geometry of outside stems

a. E1 monolith -- no culvert or void.

b. E2 monolith -- with culvert, no void.

c. E3 monolith -- both culvert and void.

When a center stem is present, the program provides for the analysis of a W-frame structure. The center stem is assumed to be symmetric and to conform to one of the geometries shown in Figure 2. Each of these configurations will be designated by a monolith identifier as follows:

a. C1 monolith -- no culvert or void.

b. C2 monolith -- one culvert, no void.

c. C3 monolith -- no culvert, closed void.

d. C4 monolith -- no culvert, open void.

e. C5 monolith -- one culvert, closed void.

f. C6 monolith -- one culvert, open void.

g. C7 monolith -- two culverts, no void.

h. C8 monolith -- two culverts, closed void.

i. C9 monolith -- two culverts, open void.

The typical sections in Figure 1 are shown for the rightside[1] outer stem of the structure. When the structure is symmetric about the centerline, only the right-half stem data need be provided and a mirror image will be created for the leftside. In an unsymmetric system, the rightside and leftside must be described and the outside stems need not be the same type. The geometry of the outer stems is restricted to the three types illustrated in Figure 1 and must conform to the limitations for the "frame analysis mode" described by Jordan and Dawkins.[2]

In all cases, the structure is assumed to be monolithic, mass concrete. The effects of reinforcement, construction joints, expansion joints, or other discontinuities (e.g., cracking) in the system are not taken into account. In the frame analysis to be described later, the concrete is assumed to be linearly elastic and homogeneous.

---

1 The terms "rightside," "leftside," and "centerline" are each used in a one-word form in the text to be consistent with these terms as used in the computer program CDWFRM.

2 Op. cit., p 1.

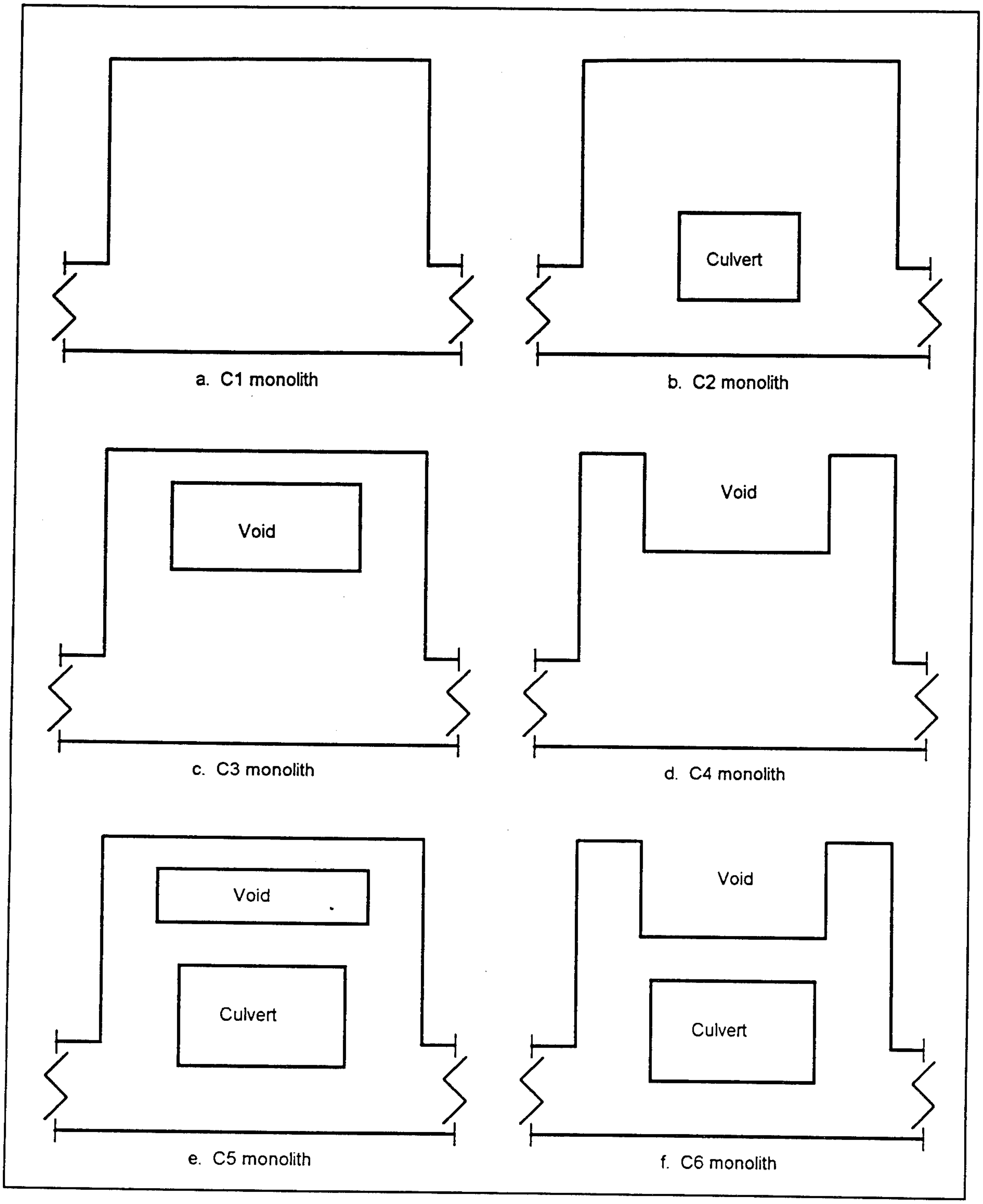


Figure 2. Geometry of center stem (Continued)

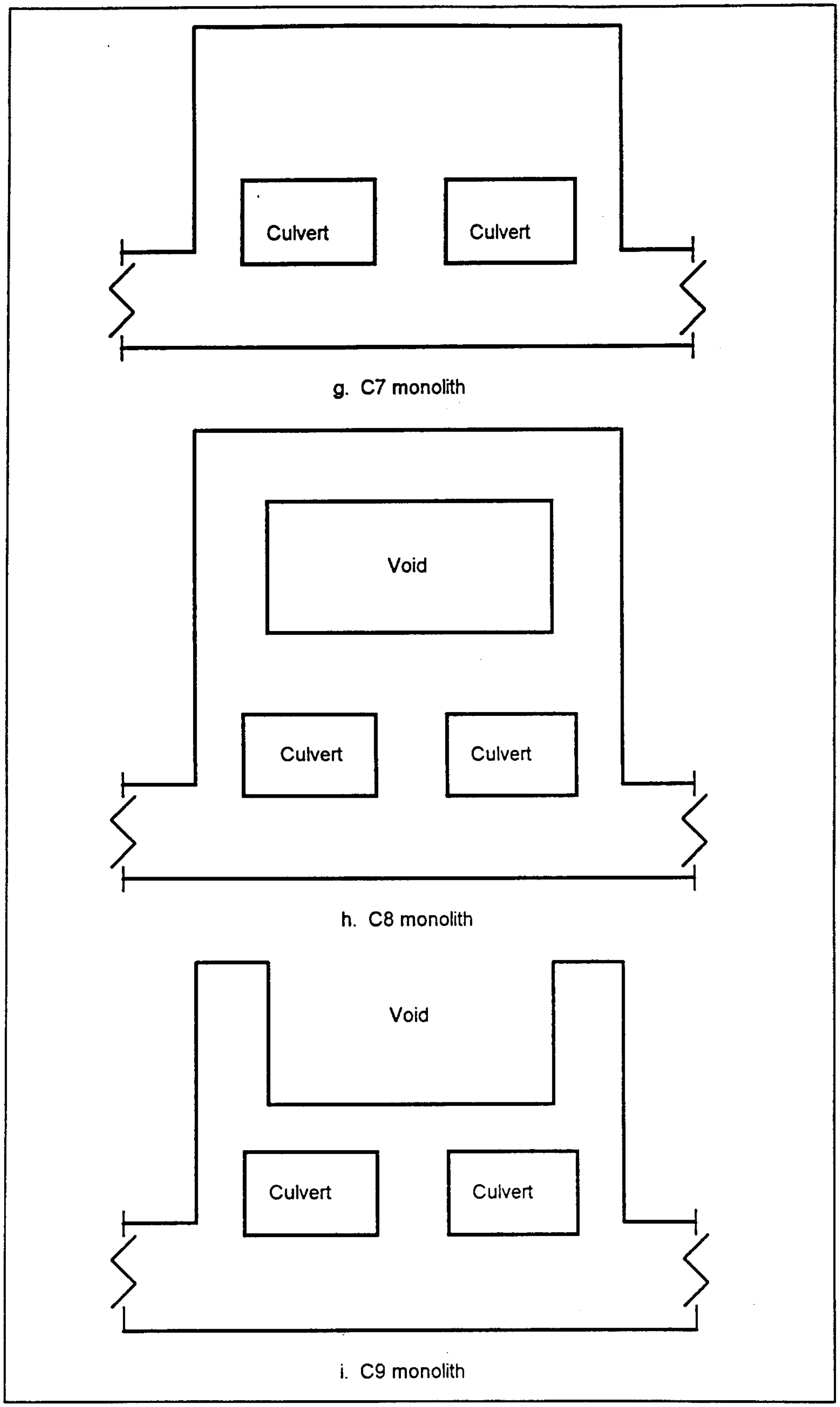


Figure 2. (Concluded)

Nomenclature, Assumptions, and Limitations

The various terms applied throughout this report and the assumptions and limitations employed (see "Appendix A: Guide for Data Input" for additional definitions and limitations) are:

a. Centerline -- vertical line midway between rightside and leftside interior faces of the outer stems or for the special case of a W-frame, vertical line of symmetry of the center stem.

b. Floor -- bottom of the chamber(s), assumed to be horizontal.

c. Base -- lower boundary of the structure, assumed to be horizontal to some distance from the centerline, then may slope up or down.

d. Stem -- an essentially vertical part of the structure above the floor.

e. Culvert -- rectangular cavity in the vicinity of the intersection of a stem and the base slab.

f. Void -- rectangular cavity in a stem above the culvert.

g. Heel -- protrusion of the base slab beyond an outside stem.

h. Elevation -- vertical distance (feet) measured positive upward from any selected datum.

i. Horizontal distance -- positive dimension (right or left), measured from centerline unless otherwise noted.

j. Stem point -- point on the outside face of an outside stem at which a change in geometry occurs; numbered sequentially downward with stem point 1 at the top of the stem.

k. Base point -- point on the base at which a change in geometry occurs; limited to two on each side of the centerline; the first point defines the limit of the horizontal segment of the base, which must extend past the face of the center stem; the second point may be above or below the first base point; for unsymmetric structures, the first base points on each side must be at the same elevation.

l. Stem face -- inner vertical boundary of an outside stem or the vertical boundaries of the center stem.

3 Frame Model

General

The geometry of the structure must conform to the limitations for the "frame analysis" mode described by Jordan and Dawkins.[1] Six variations of geometry for the outside stems (Figure 1) are permitted: E1, E2, and four alternatives of E3 (subsequently designated E31, E32, E33, E34). Nine configurations of the center stem are allowed as indicated in Figure 2. The structure is visualized as flexible segments of the structure intersecting at "rigid blocks." The geometric requirements for the structure are discussed in the following paragraphs.

E1 Monolith

An E1 monolith, Figure 3, has no culvert or void. Six stem points, S1 through S6, are required and two rigid blocks are associated with this monolith. Limitations on horizontal distance from the stem face (D_i) and elevation (E_i) are:

a. $E_1 > E_f$, $D_1 > 0$

b. $E_2 < E_1$, $D_2 = D_1$

c. $E_3 \leq E_2$, $D_3 \leq D_2$

(Stem points S1 through S3 define the top rigid block B6.)

d. $E_3 > E_4 > E_5$, $D_4 > 0$

e. $E_5 \leq E_f$, $D_5 > 0$

(Stem point S5 defines one limit of rigid block B1.)

---

[1] Op. cit., p 1.

f. $E_6 \leq E_5$, $D_6 \geq D_5$

(If $E_6 = E_5$ and $D_6 = D_5$, heel is omitted.)

g. If only one base point is provided,

$E_{B1} < E_6$, $D_{B1} = D_f + D_6$

h. If two base points are provided,

$E_{B2} < E_6$, $D_{B2} = D_f + D_6$, $D_{B1} \leq D_f + D_5$

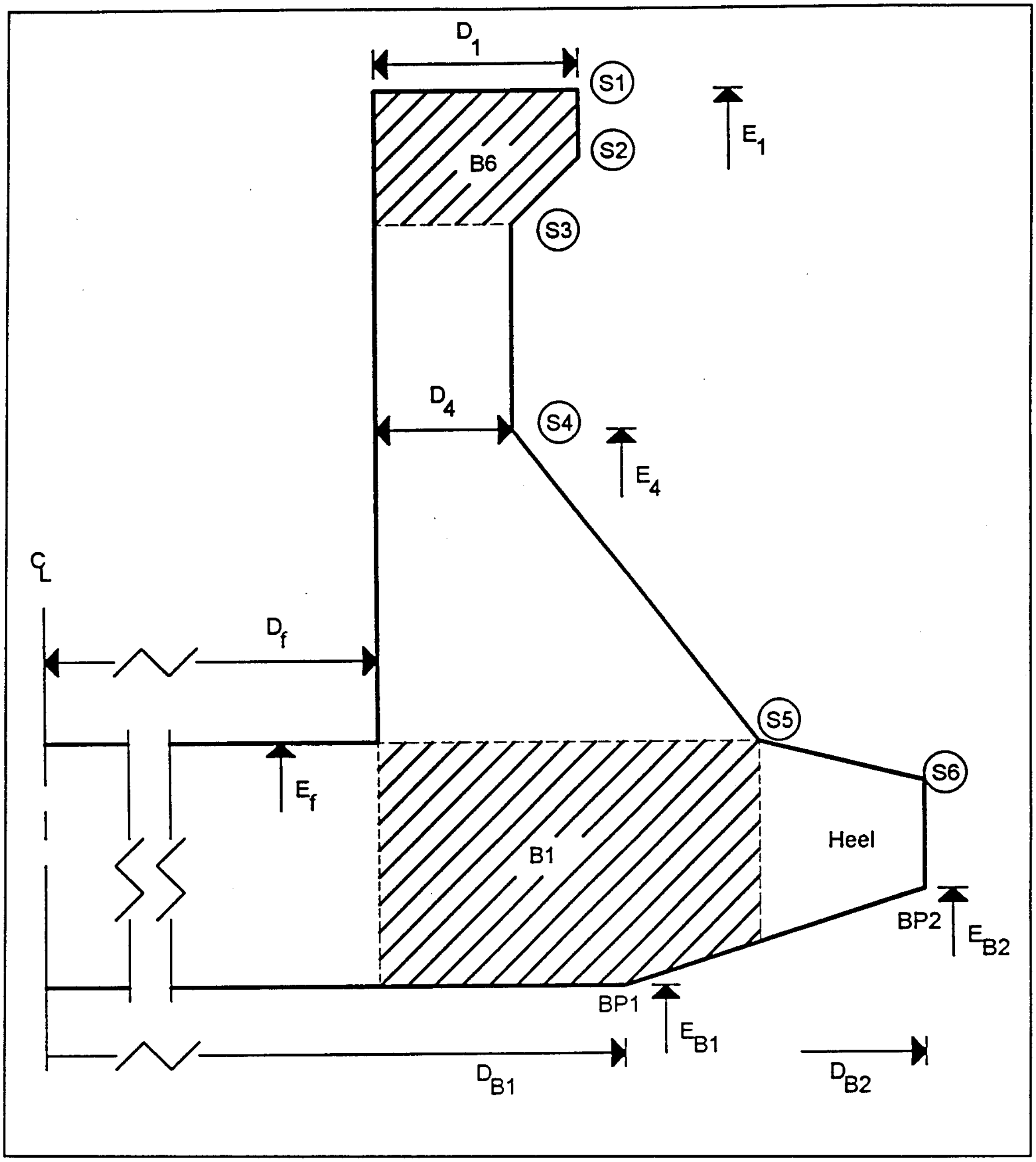


Figure 3. E1 monolith

E2 Monolith

An E2 monolith, Figure 4, has a culvert but no void. Eight stem points are required and there are five rigid blocks (B1, B2, B3, B4, and B6). The following limitations are imposed:

a. $E_1 > E_f$, $D_1 > 0$

b. $E_2 < E_1$, $D_2 = D_1$

c. $E_3 \le E_2$, $D_3 \le D_2$

(Stem points S1 through S3 define the top rigid block B6.)

d. $E_3 > E_4 > E_5$, $D_4 > 0$

e. $E_5 > E_c + H_c$, $D_5 > 0$

(Stem point S5 defines one limit of rigid block B3.)

f. $E_5 \ge E_6 > E_c + H_c$, $D_5 < D_6 > D_c + W_c$

g. $E_7 < E_6$, $D_7 > D_c + W_c$

(S7 defines one limit of block B1.)

h. $E_8 \le E_7$, $D_8 \ge D_7$

(If $E_8 = E_7$ and $D_8 = D_7$, heel is omitted.)

i. If only one base point is provided,

$E_{B1} < E_8$, $D_{B1} = D_f + D_8$

j. If two base points are provided,

$E_{B2} < E_8$, $D_{B2} = D_f + D_8$, $D_{B1} \le D_f + D_7$

k. $E_c \le E_f$, $E_f < E_c + H_c$

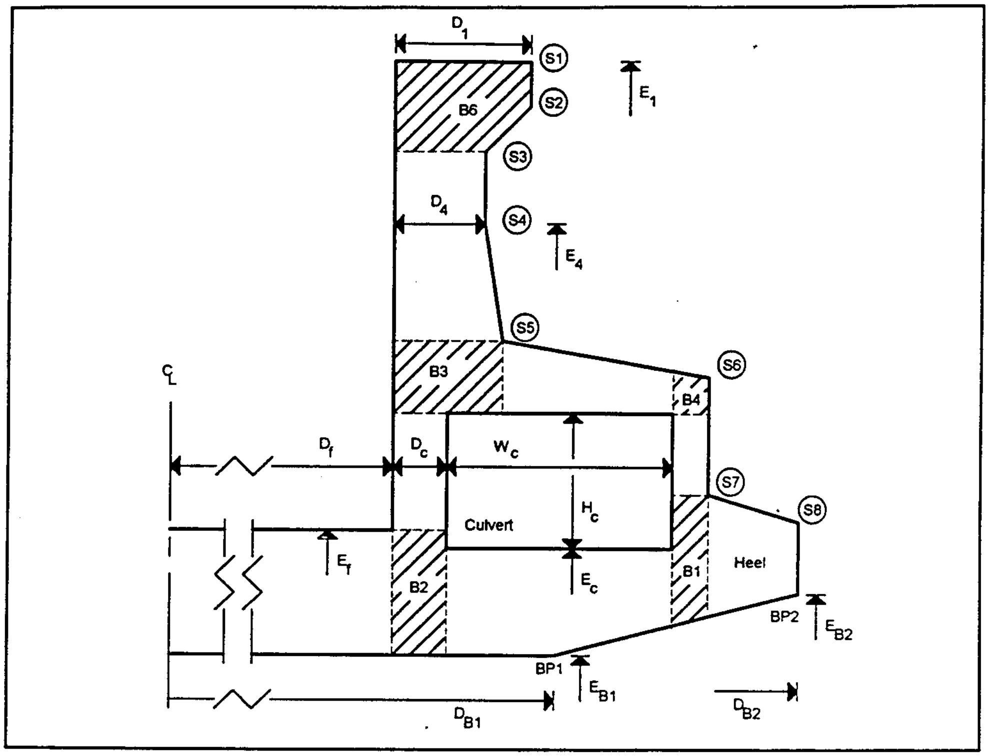


Figure 4. E2 monolith

E3 Monolith -- Variations

An E3 monolith must have both a culvert and void. Depending on the dimensions of the culvert and void, four variations (E31, E32, E33, E34) arise. Each monolith has six rigid blocks. In all cases:

$$E_c \leq E_f < E_c + H_c$$

E31 monolith

As shown in Figure 5, the culvert and void are separated (i.e., $E_v > E_c + H_c$) and the top of the void is closed ($E_1 > E_v + H_v$). Seven stem points are required. Limitations are:

a. $E_1 > E_f$, $E_1 > E_v + H_v$, $D_1 > D_v + W_v$

b. $E_2 < E_1$, $D_2 = D_1$

c. $E_2 \geq E_3 > E_v$, $D_2 \geq D_3 > D_v + W_v$

(Stem points S1, S2, S3 define block B6.)

d. $E_3 > E_4 \leq E_v$, $D_4 > D_v + W_v$

e. $E_4 > E_5 \geq E_c + H_c$, $D_5 > D_c + W_c$

f. $E_5 > E_6 < E_c + H_c$, $D_6 > D_c + W_c$

(Stem point S6 defines one limit of block 1.)

g. $E_7 \leq E_6$, $D_7 \geq D_6$

(If S6 and S7 coincide, heel is omitted.)

h. If only one base point is provided,

$E_{B1} < E_7$, $D_{B1} = D_f + D_7$

i. If two base points are provided,

$E_{B2} < E_7$, $D_{B2} = D_f + D_7$, $D_{B1} \leq D_f + D_6$

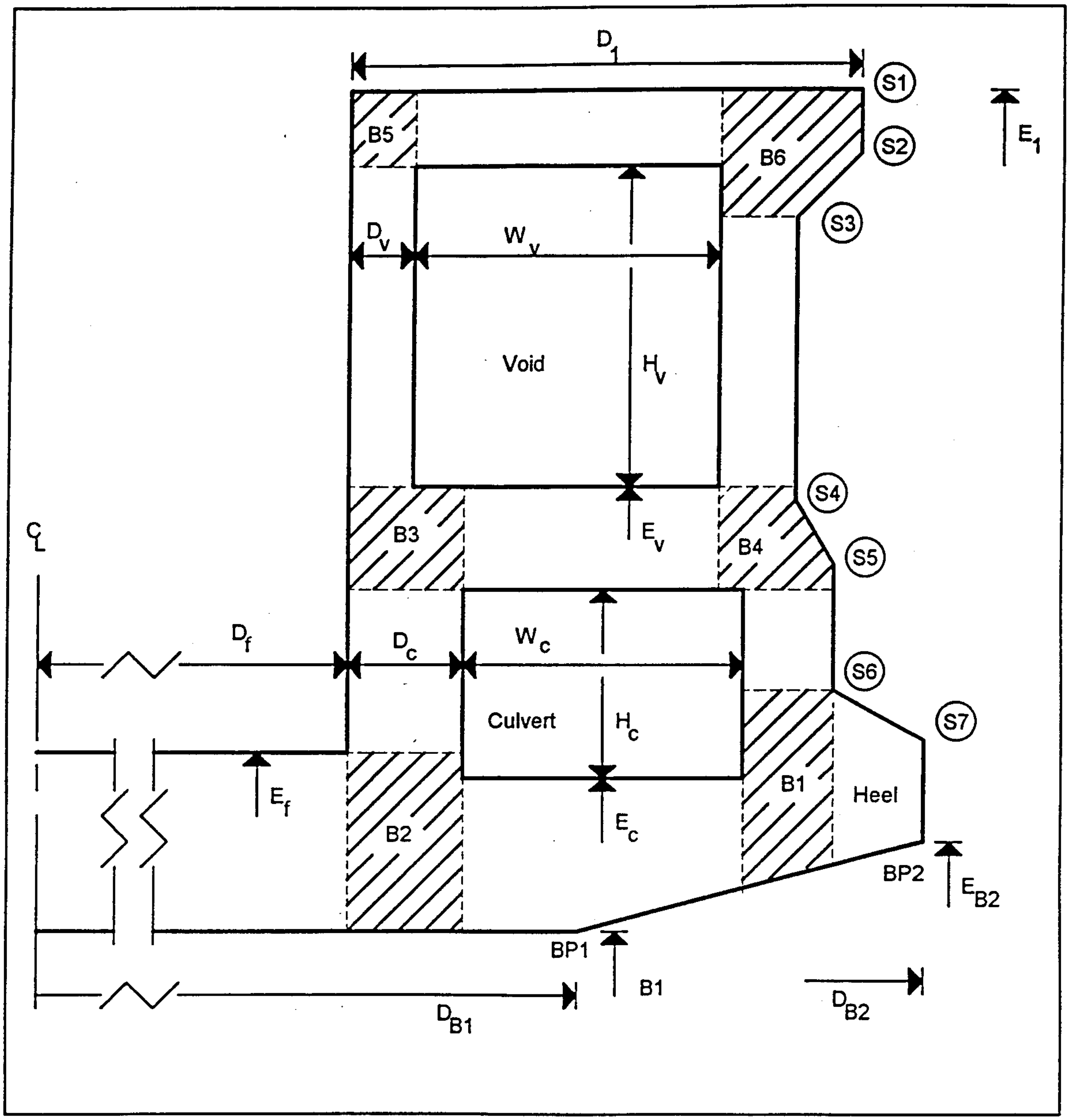


Figure 5. E31 monolith

E32 monolith

As shown in Figure 6, the culvert and void are connected (i.e., $E_v = E_c + H_c$) and the top of the void is closed ($E_1 > E_v + H_v$). Five stem points are required. Limitations are:

a. $E_1 > E_f$, $E_1 > E_v + H_v$, $D_1 > D_v + W_v$

b. $E_2 < E_1$, $D_2 = D_1$

c. $E_2 \geq E_3 > E_v$, $D_2 \geq D_3 > D_v + W_v$

(Stem points S1, S2, S3 define block B6.)

d. $E_3 > E_4 < E_v$, $D_4 > D_c + W_c$

(Stem point S4 defines one limit of block 1.)

e. $E_5 \leq E_4$, $D_5 \geq D_4$

(If S4 and S5 coincide, heel is omitted.)

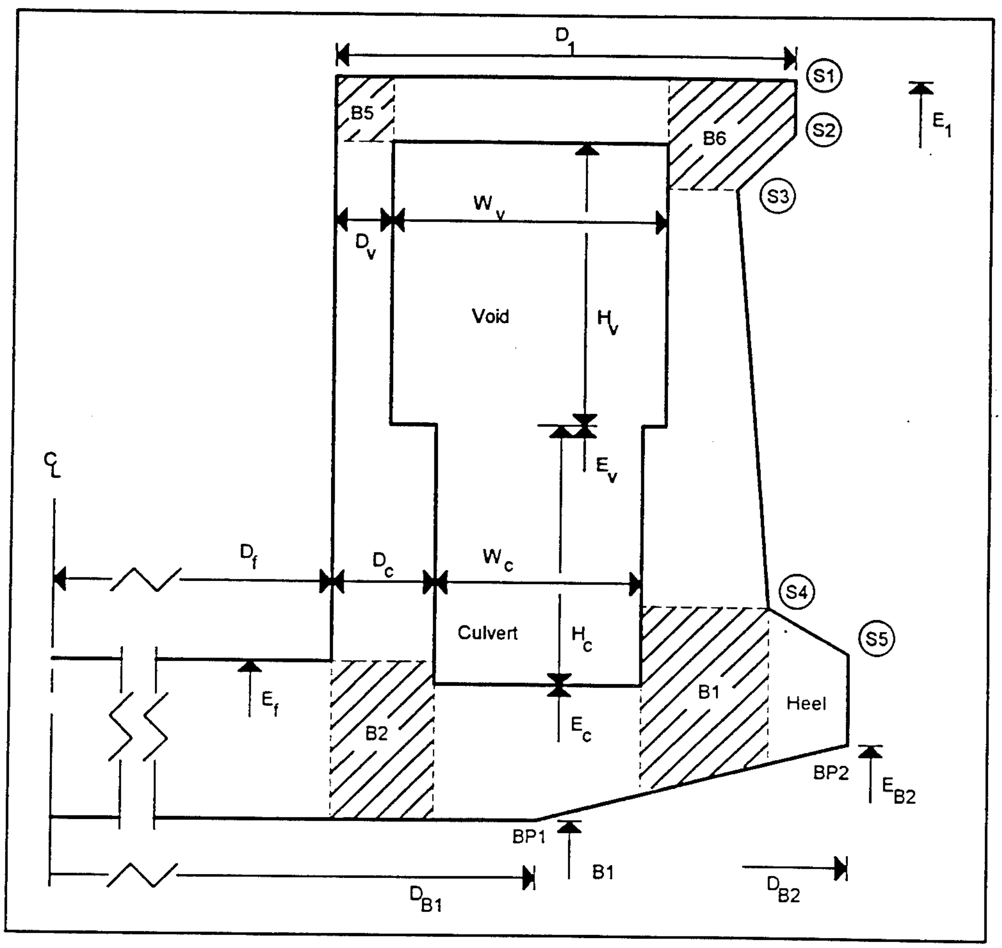


Figure 6. E32 monolith

f. If only one base point is provided,

$E_{B1} < E_5$, $D_{B1} = D_f + D_5$

g. If two base points are provided,

$E_{B2} < E_5$, $D_{B2} = D_f + D_5$, $D_{B1} \leq D_f + D_4$

E33 monolith

As shown in Figure 7, the culvert and void are separated (i.e., $E_v > E_c + H_c$) and the top of the void is open ($E_1 = E_v + H_v$). Seven stem points are required. Limitations are:

a. $E_1 > E_f$, $E_1 = E_v + H_v$, $D_1 > D_v + W_v$

b. $E_2 < E_1$, $D_2 = D_1$

c. $E_2 \geq E_3 > E_v$, $D_2 \geq D_3 > D_v + W_v$

(Stem points S1, S2, S3 define block B6.)

d. $E_3 > E_4 \leq E_v$, $D_4 > D_c + W_c$

e. $E_4 > E_5 \geq E_c + H_c$, $D_5 > D_c + W_c$

f. $E_6 < E_5$, $D_6 > D_c + W_c$

(Stem point S6 defines one limit of block B1.)

g. $E_7 \leq E_6$, $D_7 \geq D_6$

(If S6 and S7 coincide, heel is omitted.)

h. If only one base point is provided,

$E_{B1} < E_7$, $D_{B1} = D_f + D_7$

i. If two base points are provided,

$E_{B2} < E_7$, $D_{B2} = D_f + D_7$, $D_{B1} \leq D_f + D_6$

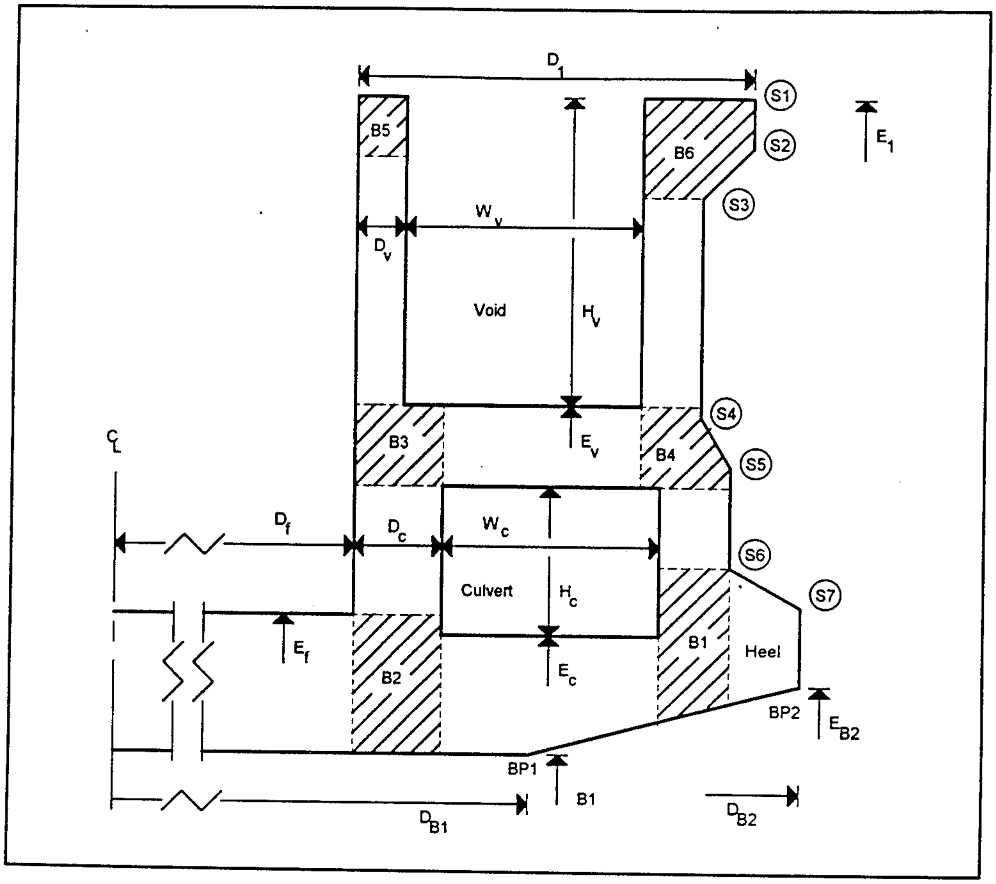


Figure 7. E33 monolith

E34 monolith

As shown in Figure 8, the culvert and void are connected (i.e., $E_v = E_c + H_c$) and the top of the void is open ($E_1 = E_v + H_v$). Five stem points are required. Limitations are:

a. $E_1 > E_f$, $E_1 = E_v + H_v$, $D_1 > D_v + W_v$

b. $E_2 < E_1$, $D_2 = D_1$

c. $E_2 \geq E_3 > E_v$, $D_2 \geq D_3 > D_v + W_v$

(Stem points S1, S2, S3 define block B6.)

d. $E_3 > E_4 < E_v$, $D_4 > D_c + W_c$

(Stem point S4 defines one limit of block 1.)

e. $E_5 \leq E_4$, $D_5 \geq D_4$

(If S4 and S5 coincide, heel is omitted.)

f. If only one base point is provided,

$E_{B1} < E_5$, $D_{B1} = D_f + D_5$

g. If two base points are provided,

$E_{B2} < E_5$, $D_{B2} = D_f + D_5$, $D_{B1} \leq D_f + D_4$

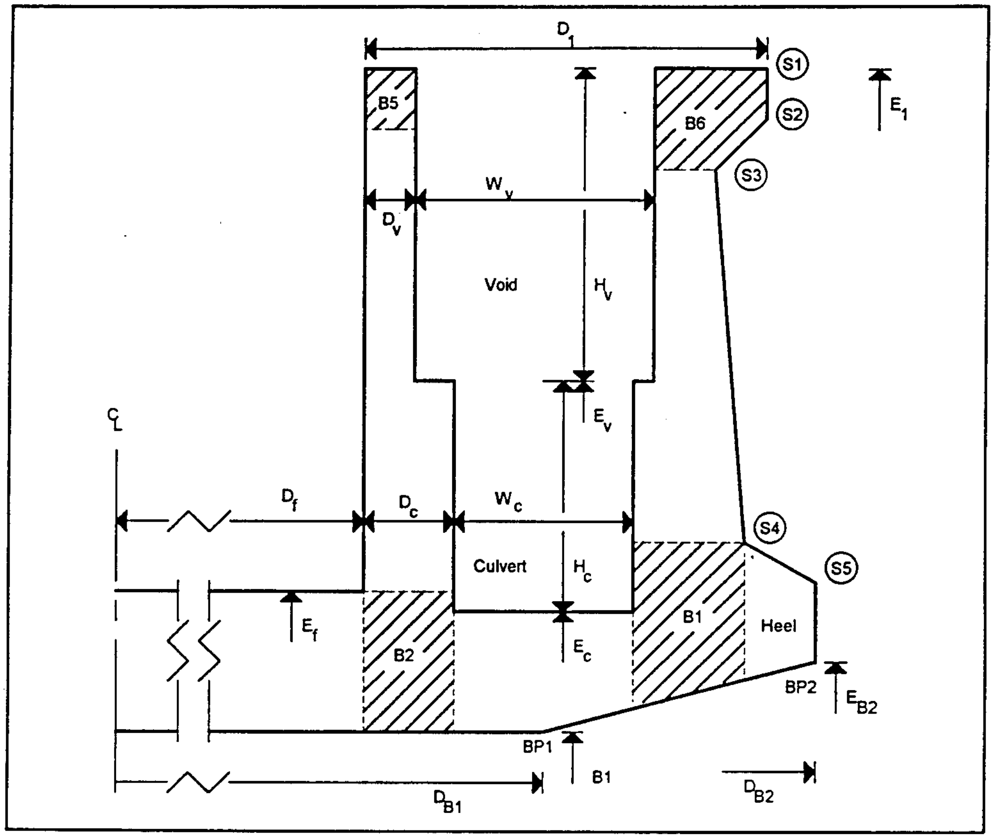


Figure 8. E34 monolith

C1 Monolith

The C1 monolith, Figure 2a, contains neither culverts nor a void. The entire center stem is treated as a single rigid block.

C2 Monolith

A C2 monolith, Figure 9, contains a single culvert and no void. There are two rigid blocks in this monolith. Limitations on dimensions are:

a. $E_s > E_c + H_c$

b. $E_c \leq E_f$

c. $W_c < W_s$

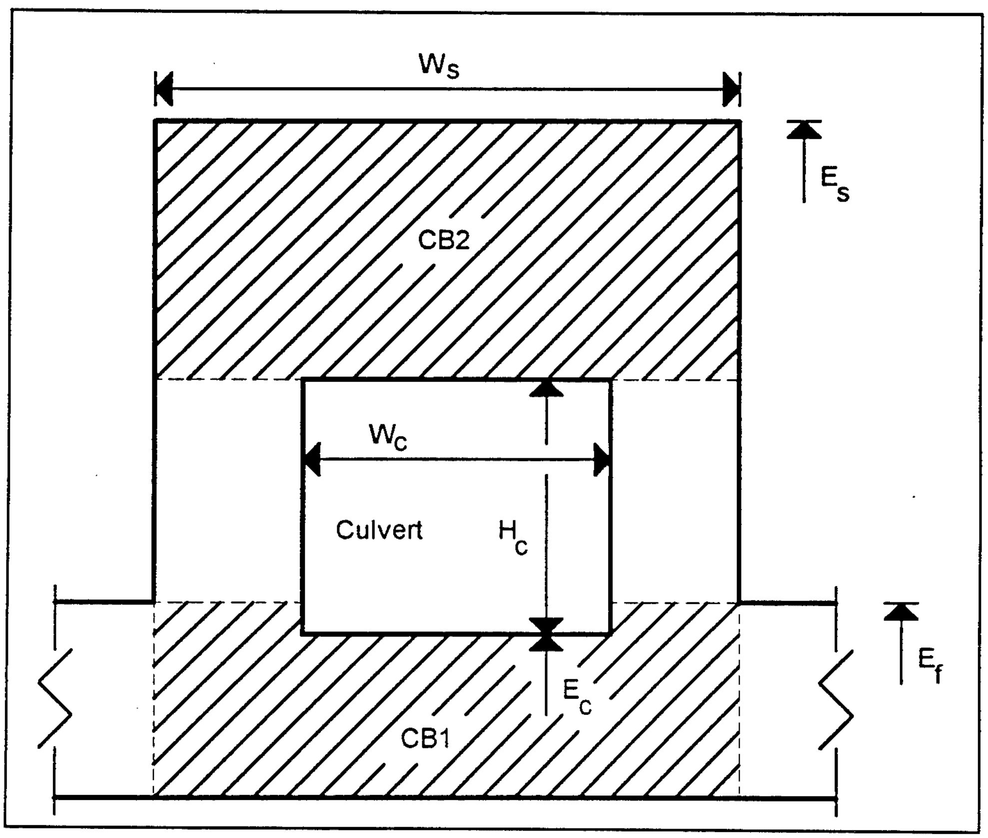


Figure 9. C2 monolith

C3 Monolith

The C3 monolith, Figure 10, has a void, closed at the top, but no culvert. There are four rigid blocks associated with this monolith. Limitations are:

a. $E_s > E_v + H_v$

b. $E_v > E_f$

c. $W_v < W_s$

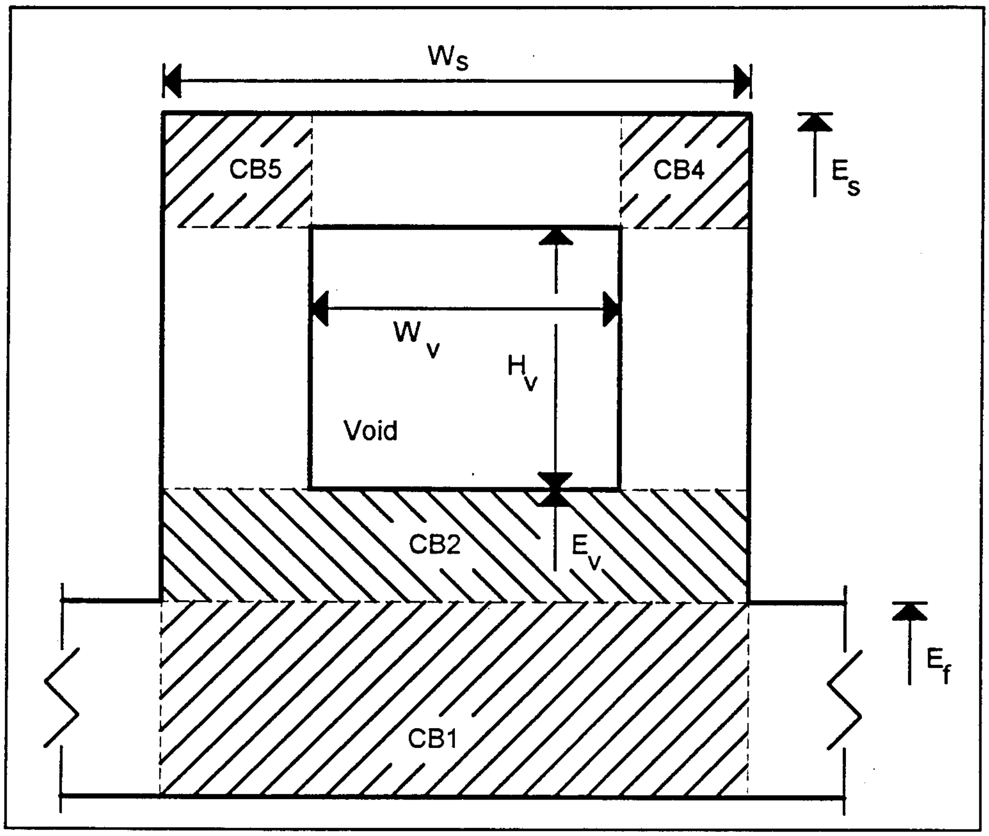


Figure 10. C3 monolith

C4 Monolith

The C4 monolith, Figure 11, has a void, open at the top, but no culvert. There are two rigid blocks in this monolith. Restrictions are:

a. $E_s = E_v + H_v$

b. $E_v > E_f$

c. $W_v < W_s$

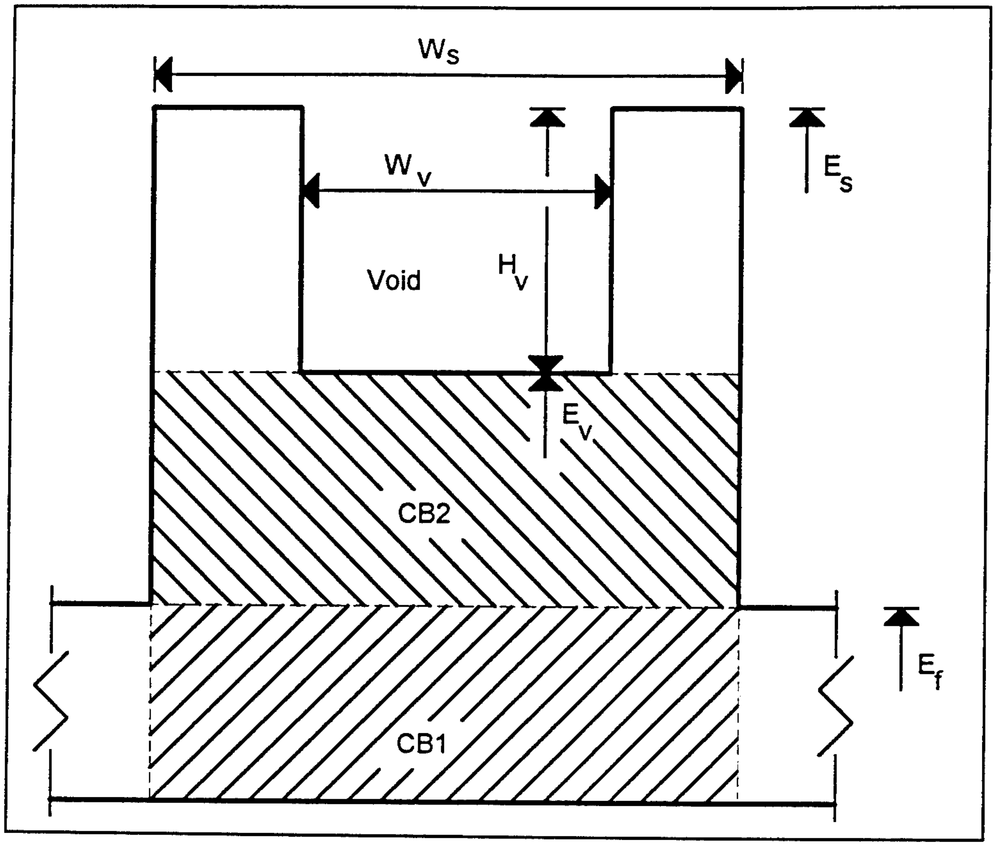


Figure 11. C4 monolith

C5 Monolith

The C5 monolith, Figure 12, has both culvert and void, with the void top closed. There are five rigid blocks in this monolith. Restrictions are:

a. $E_s > E_v + H_v$

b. $E_v > E_c + H_c$

c. $W_v < W_s$

d. $E_c \leq E_f$

e. $W_c < W_s$

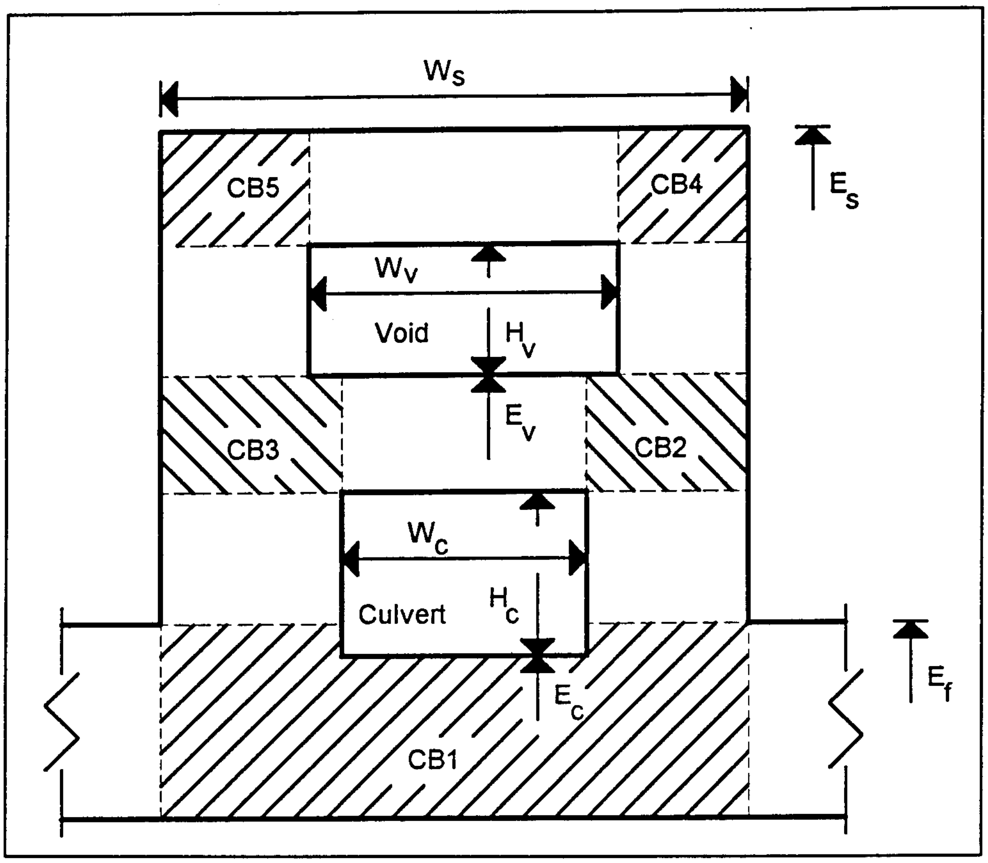


Figure 12. C5 monolith

C6 Monolith

The C6 monolith, Figure 13, has both culvert and void, with the void top open. There are three rigid blocks in this monolith. Restrictions are:

a. $E_s = E_v + H_v$

b. $E_v > E_c + H_c$

c. $W_v < W_s$

d. $E_c \leq E_f$

e. $W_c < W_s$

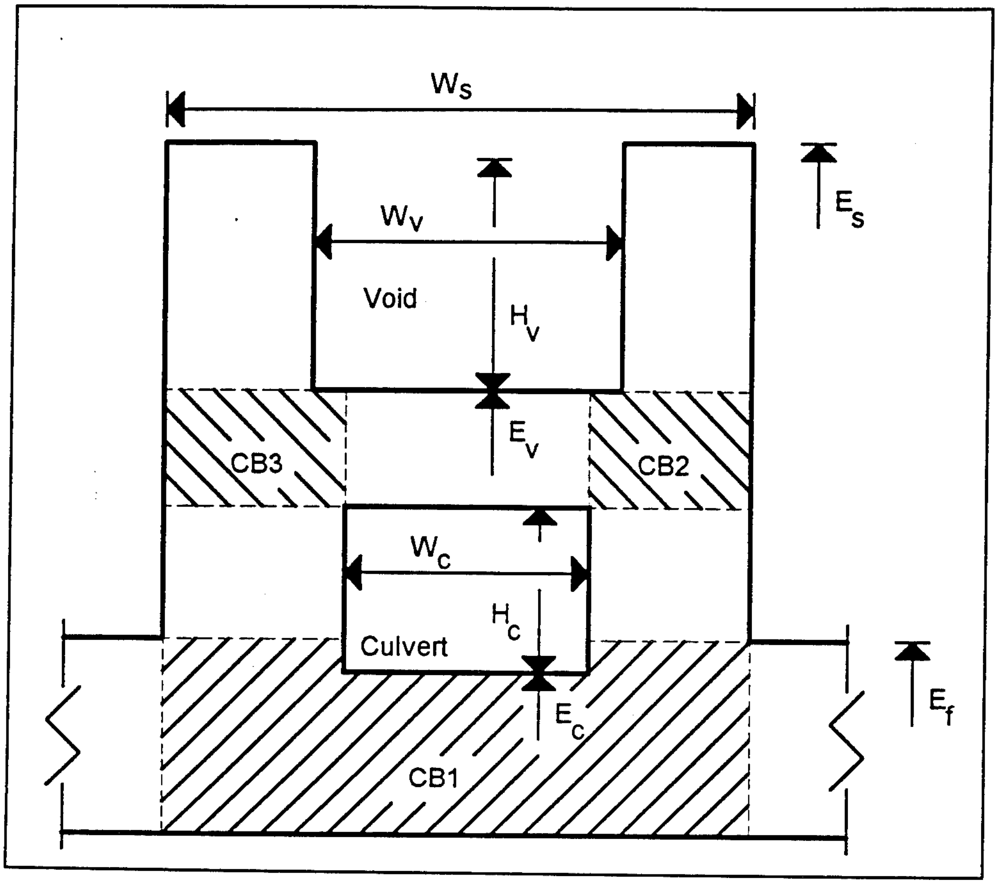


Figure 13. C6 monolith

C7 Monolith

A C7 monolith, Figure 14, contains two culverts and no void. There are two rigid blocks in this monolith. Limitations on dimensions are:

a. $E_s > E_c + H_c$

b. $E_c \leq E_f$

c. $D_c + 2 \cdot W_c < W_s$

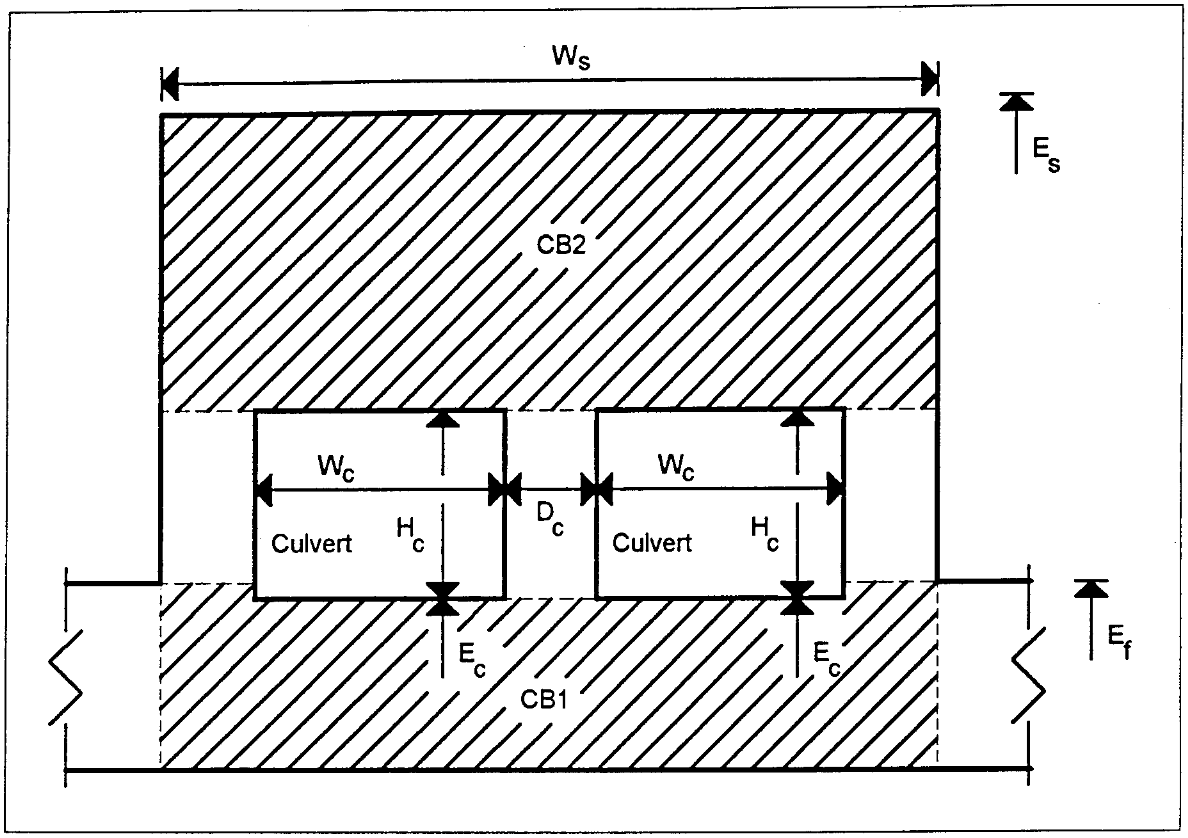


Figure 14. C7 monolith

C8 Monolith

A C8 monolith, Figure 15, contains two culverts and a void with a closed top. There are four rigid blocks in this monolith. Limitations on dimensions are:

a. $E_s > E_v + H_v$

b. $E_v > E_c + H_c$

c. $W_v < W_s$

d. $E_c \leq E_f$

e. $D_c + 2 \cdot W_c < W_s$

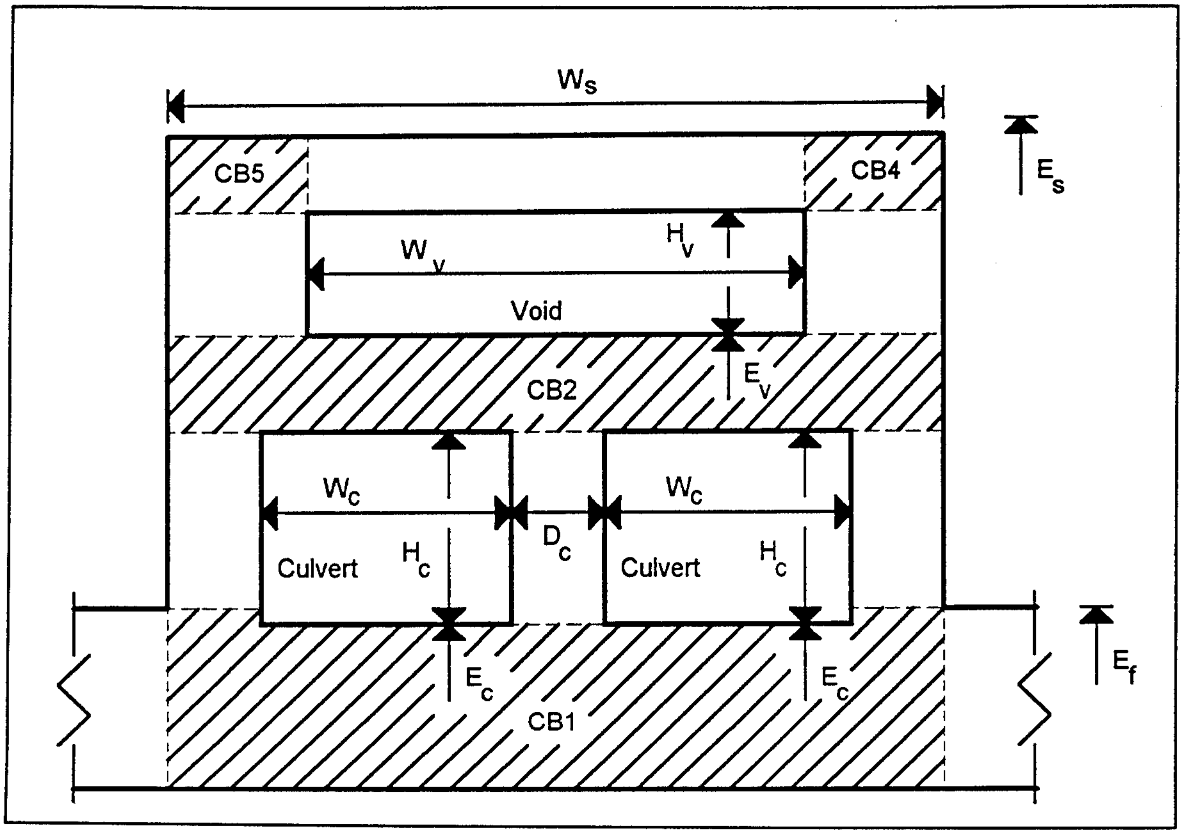


Figure 15. C8 monolith

C9 Monolith

A C9 monolith, Figure 16, contains two culverts and a void with an open top. There are two rigid blocks in this monolith. Limitations on dimensions are:

a. $E_s = E_v + H_v$

b. $E_v > E_c + H_c$

c. $W_v < W_s$

d. $E_c \leq E_f$

e. $D_c + 2 \cdot W_c < W_s$

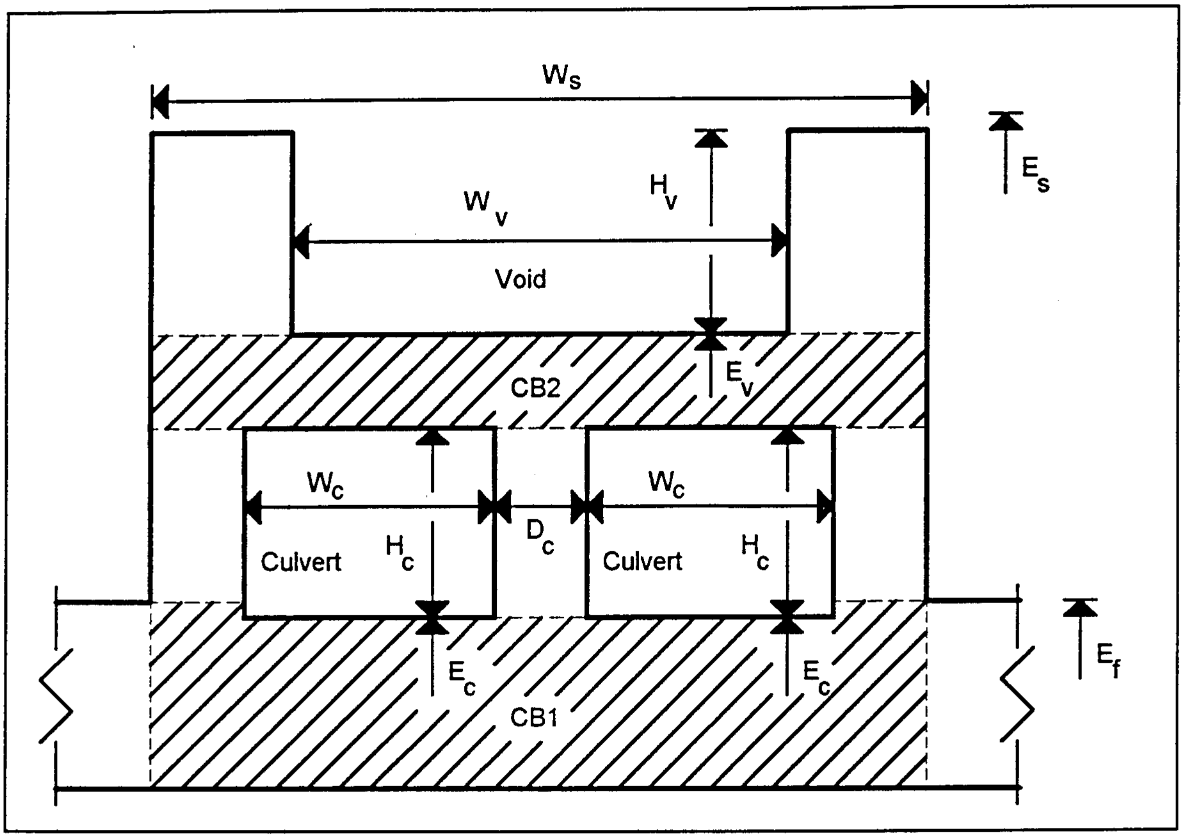


Figure 16. C9 monolith

Structural Model

Structure stiffnesses

The locations of joints, configurations of the flexible members employed in the structural model, and development of the member, pile, and structure stiffness matrices are described in detail by Jordan and Dawkins.[1]

Structure Mass

Member mass matrix

A typical member, Figure 17, consists of a flexible portion between a and b connected to adjacent joints i and j by rigid links.

[1] Op. cit., p 1.

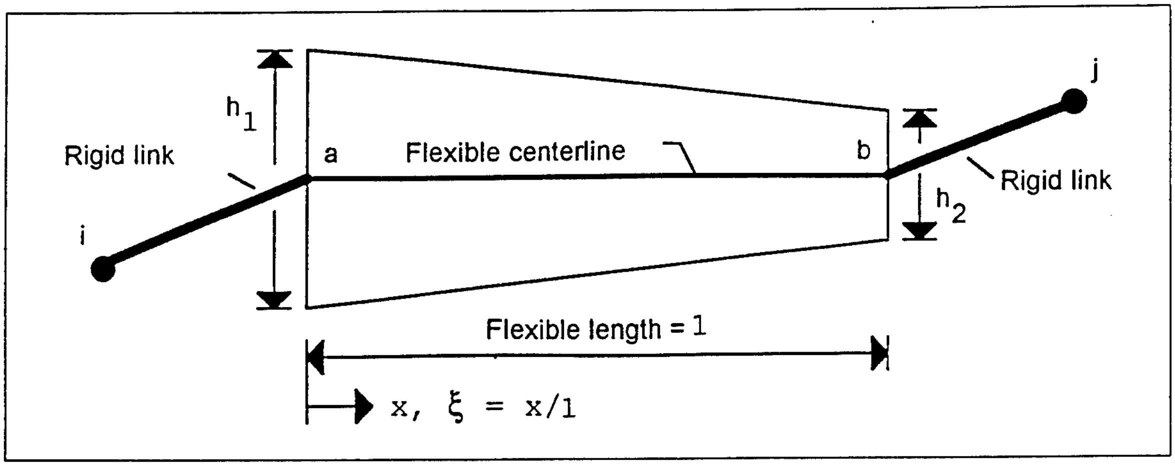


Figure 17. Typical member

The forces and accelerations are shown in Figure 18 for a local coordinate system with an origin at a.

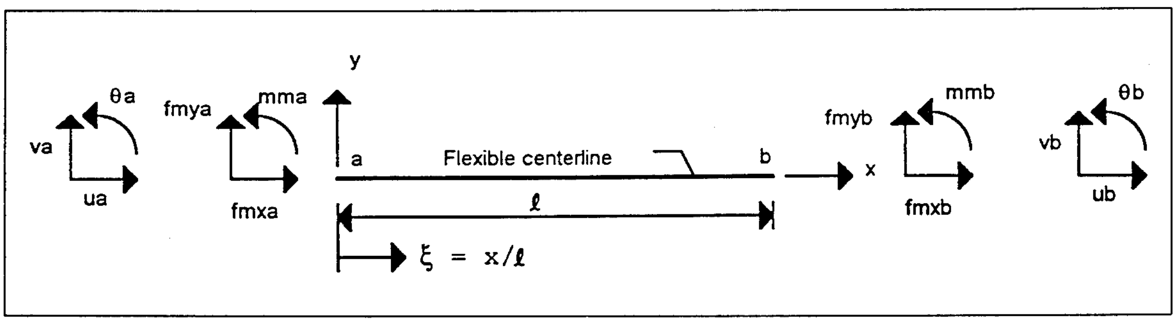


Figure 18. Inertia forces and accelerations at ends of flexible length

A "consistent" mass matrix[1] is used to relate the inertia forces at a and b to accelerations as follows:

$$\{f_m\}_{ab} = [M]_{ab}\,\{\ddot{U}\}_{ab} \tag{1}$$

where

$$\{f_m\}_{ab}^T = \{f_{mxa}\ \ f_{mya}\ \ m_{ma}\ \ f_{mxb}\ \ f_{myb}\ \ f_{mb}\}$$

$$\{\ddot{U}\}_{ab}^T = \{\ddot{u}_a\ \ \ddot{v}_a\ \ \ddot{\theta}_a\ \ \ddot{u}_b\ \ \ddot{v}_b\ \ \ddot{\theta}_b\}$$

1 R. W. Clough, and J. Penzien. (1993). *Dynamics of structure*. McGraw-Hill, New York.

and $[M]_{ab}$ = six by six symmetric matrix. Nonzero elements of $[M]_{ab}$ due to member self-weight are given by

$$m_{11} = \int_0^1 m_\xi \cdot [1-\xi]^2 \cdot \ell \cdot d\xi, \quad m_{14} = \int_0^1 m_\xi \cdot [1-\xi] \cdot \xi \cdot \ell \cdot d\xi, \tag{2}$$

$$m_{44} = \int_0^1 m_\xi \cdot \xi^2 \cdot \ell \cdot d\xi$$

and for i = 2, 3, 5, 6 and j = 2, 3, 5, 6

$$m_{ij} = \int_0^1 m_\xi \cdot \psi_{\xi,i} \cdot \psi_{\xi,j} \cdot \ell \cdot d\xi + \int_0^1 \frac{I_\xi}{\ell} \cdot \frac{d\psi_{\xi,i}}{d\xi} \cdot \frac{d\psi_{\xi,j}}{d\xi} \cdot d\xi \tag{3}$$

where

$$\psi_{\xi,2} = 2\xi^3 - 3\xi^2 + 1$$

$$\psi_{\xi,3} = \ell \cdot (\xi^3 - 2\xi^2 + 1)$$

$$\psi_{\xi,5} = -2\xi^3 + 3\xi^2$$

$$\psi_{\xi,6} = \ell \cdot (\xi^3 - \xi^2)$$

$$m_\xi = \frac{\gamma_c B}{g} \cdot \left[h_1 \cdot (1 -- \xi) + h_2 \cdot \xi\right]$$

$$I_\xi = \frac{\gamma_c B}{12g} \left[h_1 \cdot (1 - \xi) + h_2 \cdot \xi\right]^3$$

γ_c = unit weight of concrete

B = width of 2-D slice under analysis

g = acceleration of gravity

Evaluations of the various terms are given in Figure 19.

$$m_{11} = \frac{\gamma_c B \ell}{10080g}(2520h_1 + 840h_2)$$

$$m_{14} = \frac{\gamma_c B \ell}{10080g}(840h_1 + 840h_2)$$

$$m_{22} = \frac{\gamma_c B}{10080g}[\ell\left(2880h_1 + 864h_2\right) + \frac{1}{\ell}\left(180h_1^3 + 324h_1^2 h_2 + 324h_1 h_2^2 + 180h_2^3\right)]$$

$$m_{23} = \frac{\gamma_c B}{10080g}[\ell^2\left(360h_1 + 168h_2\right) + \left(-30h_1^3 + 18h_1^2 h_2 + 54h_1 h_2^2 + 42h_2^3\right)]$$

$$m_{25} = \frac{\gamma_c B}{10080g}[\ell\left(648h_1 + 648h_2\right) + \frac{1}{\ell}\left(-180h_1^3 - 324h_1^2 h_2 - 324h_1 h_2^2 - 180h_2^3\right)]$$

$$m_{26} = \frac{\gamma_c B}{10080g}[\ell^2\left(-168h_1 - 144h_2\right) + \left(42h_1^3 + 54h_1^2 h_2 + 18h_1 h_2^2 - 30h_2^3\right)]$$

$$m_{33} = \frac{\gamma_c B}{10080g}[\ell^3\left(60h_1 + 36h_2\right) + \ell\left(65h_1^3 + 21h_1^2 h_2 + 15h_1 h_2^2 + 11h_2^3\right)]$$

$$m_{35} = \frac{\gamma_c B}{10080g}[\ell^2\left(144h_1 + 168h_2\right) + (30h_1^3 - 18h_1^2 h_2 - 54h_1 h_2^2 - 42h_2^3\right)]$$

$$m_{36} = \frac{\gamma_c B}{10080g}[\ell^3\left(-36h_1 - 36h_2\right) + \ell\left(-11h_1^3 - 3h_1^2 h_2 - 3h_1 h_2^2 - 11h_2^3\right)]$$

$$m_{44} = \frac{\gamma_c B \ell}{10080g}\left(840h_1 + 2520h_2\right)$$

$$m_{55} = \frac{\gamma_c B}{10080g}[\ell\left(864h_1 + 2880h_2\right) + \frac{1}{\ell}\left(180h_1^3 + 324h_1^2 h_2 + 324h_1 h_2^2 + 180h_2^3\right)]$$

$$m_{56} = \frac{\gamma_c B}{10080g}[\ell^2\left(-168h_1 - 360h_2\right) + \left(-42h_1^3 - 54h_1^2 h_2 - 18h_1 h_2^2 + 30h_2^3\right)]$$

$$m_{66} = \frac{\gamma_c B}{10080g}[\ell^3\left(36h_1 + 60h_2\right) + \ell\left(11h_1^3 + 15h_1^2 h_2 + 21h_1 h_2^2 + 62h_2^3\right)]$$

Figure 19. Nonzero elements of member mass matrix due to self-weight

Additional weights

A U- or W-frame will usually be in contact with surrounding soil and/or water which will interact with the motions of the structure. No provision is made in CDWFRM for directly including soil or water effects in the analysis. These effects may be approximated by specification of weights of materials attached to the periphery of the concrete structure. Additional weights may be described as responding to either horizontal or vertical accelerations of the points to which they are attached. Additional weights are converted to masses and are included in the assessment of the member mass matrix by procedures similar to those described for evaluating the member fixed end forces due to "additional loads" described by Jordan and Dawkins.[1]

Pile head mass matrices

Soil surrounding the embedded length of the piles will interact with accelerations of the piles to produce additional inertia forces on the system. Although provision is made for the program to evaluate the pile head stiffness matrix from strength and weight properties of the soil, the user must explicitly provide the three by three pile head mass matrix for the local pile coordinate system described by Jordan and Dawkins.[1]

Rigid block masses

Translational and rotatory inertias of the mass encompassed by a rigid block, including the mass associated with any additional weights acting on the exterior surfaces of the block are assigned directly to the structural joint at the block centroid.

[1] Op. cit., p 1.

4 Dynamic Analysis

General

It is assumed that the dynamic excitation of the system is produced by an earthquake acceleration of the structure foundation in the horizontal or vertical direction, exclusively. It is further assumed that the earthquake effect is described by a response spectrum of spectral acceleration versus period.[1]

Equation of Motion

Under the above assumptions, the governing equation of motion of the system, due to earthquake excitation, is

$$[M]\{\ddot{U}\} + [K]\{U\} = -\ddot{x}_g [M]\{\Lambda\} \tag{4}$$

where

$[M]$ and $[K]$ = 3N by 3N mass and stiffness matrices, respectively, for a structural model with N joints

$\{\ddot{U}\}$ and $\{U\}$ = 3N by one vector of joint accelerations and displacements, respectively, relative to the ground motion

$\ddot{x}_g$ (t) = time-wise variation of ground acceleration

$\{\Lambda\}$ = 3N by one vector composed of N three by one partitions $\tilde{\lambda}$ with

$\tilde{\lambda} = [1\ 0\ 0]^T$ for horizontal ground acceleration or

---

[1] Op. cit., p 28.

$\lambda = [0\ 1\ 0\ ]^T$ for vertical ground acceleration

Frequencies and Mode Shapes

Free vibration frequencies and mode shapes of the undamped system are calculated using successive Jacobean transformations applied to the mass and stiffness matrices by the process described by Bathé and Wilson.[1]

The pseudo-static forces at the ends of each member and at each pile head are determined for the fifty lowest modes of vibration. The response of the structural model for each mode shape is available for output.

Modal Combinations

The maximum response of the structure to an earthquake is estimated by a complete quadratic combination[2] of the responses of the 50 lowest modes. The combination process, applied individually to member end forces, pile head forces, and displacements, is given by

$$r_{\max} = \sqrt{\sum_{i=1}^{50}\sum_{j=1}^{50} |r_i \cdot f_i \cdot \rho_{ij} \cdot r_j \cdot f_j|} \tag{5}$$

where

r_i and r_j = response values (e.g., member end force, pile head force, or joint displacement) for the i^{th} and j^{th} modes, respectively

f_i and f_j = modal "participation" factors for the i^{th} and j^{th} modes, respectively

ρ_{ij} = "cross-modal" coefficient for the i^{th} and j^{th} modes

The "participation" factor is given by

$$f_i = \frac{1}{\omega_i^2}\frac{\phi_i^T M \Lambda}{\phi_i^T M \phi} S_{ai} \tag{6}$$

---

1 K-J. Bathé and E. L. Wilson. (1976). *Numerical methods in finite element analysis.* Prentice Hall, New York.

2 M. Paz. (1990). *Structural dynamics.* Van Nostrand Reinhold, New York.

where

ϕ_i = i^{th} mode shape

M = system mass matrix

Λ = vector of ones and zeros defined previously

ω_i = i^{th} circular frequency

S_{ai} = spectral acceleration for the i^{th} mode obtained from the acceleration response spectrum provided as input to the program

The "cross-modal" coefficient is given by

$$\rho_{ij} = \frac{8\lambda^2(1 + \zeta)\zeta^{3/2}}{\left(1 - \zeta^2\right) + 4\lambda^2\zeta(1 + \zeta)^2} \tag{7}$$

where

λ = damping ratio

$\zeta = \omega_j / \omega_j$

5 Computer Program

General

Program CDWFRM is written in the FORTRAN programming language for interactive operation on IBM-PC or compatible microcomputers with 80386/80387 or 80486 processors, eight megabytes of extended memory, and a minimum of five megabytes of hard disk storage available. All arithmetic operations are performed in double precision.

Input Data

Input data may be provided interactively from the keyboard during execution or from a previously prepared data file. When data are input from the keyboard, the program provides prompting messages to indicate the type and amount of input data to be entered. The characteristics of a previously prepared input data file are described in the "Guide for Data Input" in Appendix A.

Whenever an input sequence is completed, the program provides an opportunity to change any or all parts of the input data in an editing mode. Any data section or subsection selected for editing must be entered in its entirety.

Whenever any input data are entered from the keyboard, the program provides for saving the existing input data in a permanent file in input file format.

Tabular Output Data

Several options are available regarding the amount and destination of the output from the program. Tabular output may be directed to the user's monitor, to an output file, or to both simultaneously. Available tabular output consists of:

a. An optional echoprint of input data.

b. An optional tabulation of all dimensions and characteristics of the frame model, including:

(1) Locations of points defining the rigid blocks of the system.

(2) Coordinates of the joints of the model.

(3) Member joint connectivity and dimensions.

(4) Pile head locations and stiffness coefficients.

c. An optional tabulation of the joint displacements, member end forces, and pile head forces associated with any selected mode(s) of vibration of the system.

d. A tabulation of maximum joint displacements, member end forces, and pile head forces resulting from the complete quadratic combination of a maximum of fifty mode shapes for the input Acceleration Spectrum.

Graphical Output

Output graphics consist of an optional display of the structural geometry and pile layout described by the input data and a schematic of the deformed structure associated with any selected mode(s) of the system.

Units

The program expects all dimensions to be provided in units of inches, feet, and pounds as described in the "Guide for Data Input" in Appendix A. No provision is made for conversion to any other system of units.

6 Example Solution

General

The example presented in this section is intended to illustrate the execution of the program and is not to be construed as a recommendation for its use.

System

A schematic of the right half of a pile supported W-frame structure is shown in Figure 20.

The input data file for the system is given in Figure 21 and an echoprint of the input data is shown in Figure 22.

Graphical displays of the structural geometry and pile layout for the right-side of the symmetrical system are shown in Figures 23 and 24. It should be noted that the vertical pile on the structure centerline is included only once in the analysis even though it is shown with both the left- and rightsides of the structure in subsequent tabulations.

Details of the structural model generated by CDWFRM are tabulated in Figure 25. The model contains 46 joints, 47 members, 43 piles, and 138 degrees of freedom (i.e., 138 modes of vibration).

Following development of the model, the program determines all 138 natural frequencies and mode shapes for the system. However, only the modes corresponding to the lowest 50 natural frequencies are retained for the analysis. Upon completion of extraction of the natural frequencies and mode shapes, the user is allowed to output the response (displacements, member end forces, and pile head forces) associated with any or all of the 50 lowest modes. Tabulation of the system response for mode 1 is shown in Figure 26. Plots of the deformed shape of the structure for any of the lowest 50 modes are available. A plot for the lowest mode is shown in Figure 27.

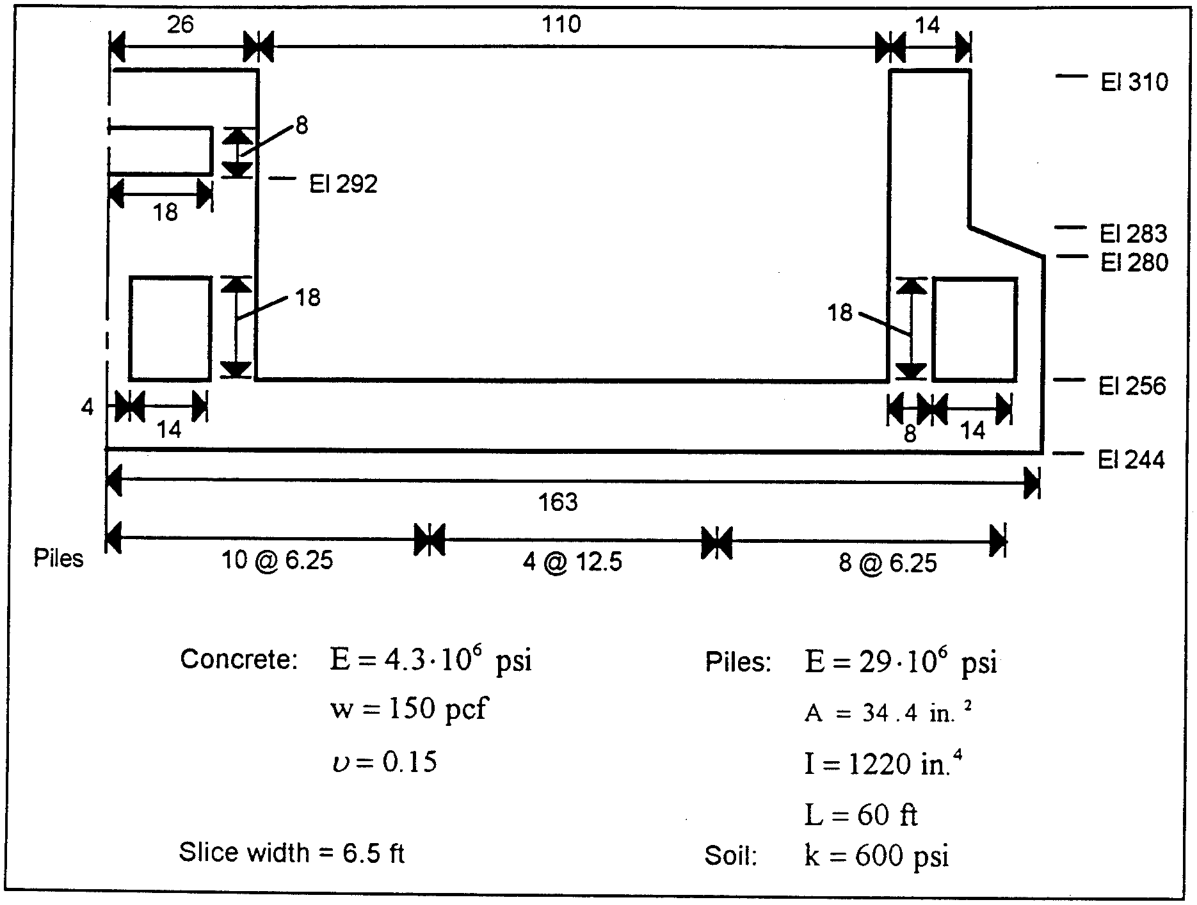


Figure 20. System for example solution

A complete quadratic combination of joint displacements, member end forces, and pile head forces is performed for the 50 lowest modes for the Acceleration Spectrum provided as input to the program. The results of the quadratic combination are shown in Figure 28. The numerical values obtained by the combination are estimates of the maximum responses of the system. These maxima do not necessarily occur at the same time. For example, the maximum end forces reported for any member do not represent an equilibrium for the member.

```
1000 'EXAMPLE 1 -- W-FRAME STRUCTURE
1010 'SUPPORTED ON FIXED HEAD PILES
1020 STRUCTURE 3.4E6 0.15 150 6.5 1.0
1030 FLOOR 136 256 0
1040 BASE BOTH 163 244
1050 STEM BOTH 8
1060 14 310 14 306 14 298 14 290 14 283
1070 27 280 27 256 27 246
1080 CULVERT BOTH 8 14 256 18
1090 STEM CENTER 52 310
1100 CULVERT CENTER 2 14 256 18 8
1110 VOID CENTER 36 292 8
1120 PILE BOTH
1130 LAYOUT 1 0 10 1 6.25
1140 LAYOUT 11 68.75 14 1 12.5
1150 LAYOUT 15 112.5 22 1 6.25
1160 PROPERTIES 1 2.9E7 34.4 1220 60 0.76 1 600 0 22 1
1170 ACCELERATION     HORIZONTAL 78    0.05
1180 .020 .500 .030 .502 .040 .505 .042 .511 .044 .517
1190 .046 .523 .048 .528 .050 .534 .055 .581 .060 .628
1200 .065 .743 .070 .869 .075 1.004 .080 1.150 .085 1.170
1210 .090 1.190 .095 1.209 .100 1.227 .110 1.235 .120 1.242
1220 .130 1.248 .140 1.254 .150 1.260 .160 1.265 .170 1.271
1230 .180 1.275 .190 1.280 .200 1.284 .220 1.292 .240 1.300
1240 .260 1.307 .280 1.306 .300 1.279 .320 1.242 .340 1.201
1250 .360 1.162 .380 1.125 .400 1.091 .420 1.059 .440 1.023
1260 .460 .984 .480 .949 .500 .918 .550 .847 .600 .776
1270 .650 .716 .700 .664 .750 .619 .800 .579 .850 .544
1280 .900 .513 .950 .486 1.000 .460 1.100 .415 1.200 .374
1290 1.300 .338 1.400 .306 1.500 .274 1.600 .244 1.700 .218
1300 1.800 .196 1.900 .177 2.000 .159 2.200 .128 2.400 .105
1310 2.600 .087 2.800 .073 3.000 .060 3.200 .051 3.400 .043
1320 3.600 .037 3.800 .032 4.000 .028 4.200 .024 4.400 .021
1330 4.600 .019 4.800 .017 5.000 .015
1340 FINISHED
```

Figure 21. Input file for example solution

```
PROGRAM CDWFRM - DYNAMIC ANALYSIS OF TWO-DIMENSIONAL U/W-FRAME STRUCTURES
DATE 24-MAY-1994                                             TIME 11.34.29

  'EXAMPLE 1 -- W-FRAME STRUCTURE
  'SUPPORTED ON FIXED HEAD PILES

              ****************
              *  INPUT DATA  *
              ****************

 I.--STRUCTURE DATA

   I.A.--MATERIAL PROPERTIES
     MODULUS OF ELASTICITY OF CONCRETE   =    3.400E+06 (PSI)
     POISSON'S RATIO FOR CONCRETE        =     .15
     UNIT WEIGHT OF CONCRETE             =  150.0      (PCF)
     THICKNESS OF TWO-DIMENSIONAL SLICE  =    6.50     (FT)
     RIGID LINK FACTOR                   =    1.00

   I.B.--FLOOR DATA
     FLOOR WIDTH        =     136.00 (FT)
     FLOOR ELEVATION    =     256.00 (FT)

   I.C.--BASE DATA

     I.C.1.--RIGHTSIDE
     DISTANCE FROM
      CHAMBER CL       ELEVATION
         (FT)            (FT)
        163.00          244.00

     I.C.2.--LEFTSIDE
     SYMMETRIC WITH RIGHTSIDE.

   I.D.--STEM DATA

     I.D.1.--RIGHTSIDE
     DISTANCE FROM
       STEM FACE       ELEVATION
         (FT)            (FT)
         14.00          310.00
         14.00          306.00
         14.00          298.00
         14.00          290.00
         14.00          283.00
         27.00          280.00
         27.00          256.00
         27.00          246.00
```

Figure 22. Echoprint of input data for example 1 (Sheet 1 of 3)

```
I.D.2.--LEFTSIDE
SYMMETRIC WITH RIGHTSIDE.

I.D.3.--CENTER
STEM WIDTH     =      52.00 (FT)
STEM ELEVATION =     310.00 (FT)

I.E.--CULVERT DATA

I.E.1.--RIGHTSIDE
DISTANCE FROM STEM FACE TO INTERIOR SIDE =      8.00 (FT)
CULVERT WIDTH                            =     14.00 (FT)
ELEVATION AT CULVERT FLOOR               =    256.00 (FT)
CULVERT HEIGHT                           =     18.00 (FT)

I.E.2.--LEFTSIDE
SYMMETRIC WITH RIGHTSIDE

I.E.3.--CENTER (TWO SYMMETRIC CULVERTS)
DISTANCE BETWEEN CULVERTS  =      8.00 (FT)
CULVERT WIDTH              =     14.00 (FT)
ELEVATION AT CULVERT FLOOR =    256.00 (FT)
CULVERT HEIGHT             =     18.00 (FT)

I.F.--VOID DATA

I.F.1.--RIGHTSIDE
NONE

I.F.2.--LEFTSIDE
NONE

I.F.3.--CENTER
VOID WIDTH                 =     36.00 (FT)
ELEVATION  AT VOID BOTTOM  =    292.00 (FT)
VOID HEIGHT                =      8.00 (FT)

II.--BASE REACTION DATA

II.A.--RIGHTSIDE PILE DATA

II.A.1.--PILE LAYOUT DATA
<------START----->     STOP    PILE
PILE    DIST. FROM     PILE     NO.    STEP IN
 NO.    CHAMBER CL      NO.    STEP    CL DIST.
           (FT)                          (FT)
  1          .00        10       1       6.25
 11        68.75        14       1      12.50
 15       112.50        22       1       6.25
```

Figure 22. (Sheet 2 of 3)

II.A.2.--PILE PROPERTIES

<------------	------------	------------	START	------------	------------	------------	---------->	STOP	PILE
PILE NO.	MODULUS OF ELASTICITY (PSI)	SECT AREA (SQIN)	MOMENT OF INERTIA (IN**4)	LENGTH (FT)	AXIAL COEFF	HEAD FIXITY		STOP PILE NO.	PILE NO. STEP
1	2.90E+07	34.40	1220.00	60.00	.76	1.00		22	1

II.A.3.--SOIL PROPERTIES

<------	START	------>	STOP	PILE
PILE NO.	CONSTANT COEFFICIENT (PSI)	LINEAR COEFFICIENT (PCI)	STOP PILE NO.	PILE NO. STEP
1	600.000	.000	22	1

II.A.4.--PILE HEAD STIFFNESS MATRICES
NONE

II.A.4.--PILE BATTER DATA
NONE

II.A.5.--PILE HEAD MASS MATRICES
NONE

II.B.-- LEFTSIDE PILE DATA
SYMMETRIC WITH RIGHTSIDE

III.--HORIZONTAL ACCELERATION SPECTRUM

DAMPING RATIO = .050

SPECTRUM DATA

PERIOD (SEC)	SPECTRAL ACCELERATION (G'S)	PERIOD (SEC)	SPECTRAL ACCELERATION (G'S)	PERIOD (SEC)	SPECTRAL ACCELERATION (G'S)
.020	.500	.030	.502	.040	.505
.042	.511	.044	.517	.046	.523
.048	.528	.050	.534	.055	.581
.060	.628	.065	.743	.070	.869
.075	1.004	.080	1.150	.085	1.170
.090	1.190	.095	1.209	.100	1.227
.110	1.235	.120	1.242	.130	1.248
.140	1.254	.150	1.260	.160	1.265
.170	1.271	.180	1.275	.190	1.280
.200	1.284	.220	1.292	.240	1.300
.260	1.307	.280	1.306	.300	1.279
.320	1.242	.340	1.201	.360	1.162
.380	1.125	.400	1.091	.420	1.059
.440	1.023	.460	.984	.480	.949
.500	.918	.550	.847	.600	.776
.650	.716	.700	.664	.750	.619
.800	.579	.850	.544	.900	.513
.950	.486	1.000	.460	1.100	.415
1.200	.374	1.300	.338	1.400	.306
1.500	.274	1.600	.244	1.700	.218
1.800	.196	1.900	.177	2.000	.159
2.200	.128	2.400	.105	2.600	.087
2.800	.073	3.000	.060	3.200	.051
3.400	.043	3.600	.037	3.800	.032
4.000	.028	4.200	.024	4.400	.021
4.600	.019	4.800	.017	5.000	.015

IV.--ADDITIONAL WEIGHT DATA
NONE

Figure 22. (Sheet 3 of 3)

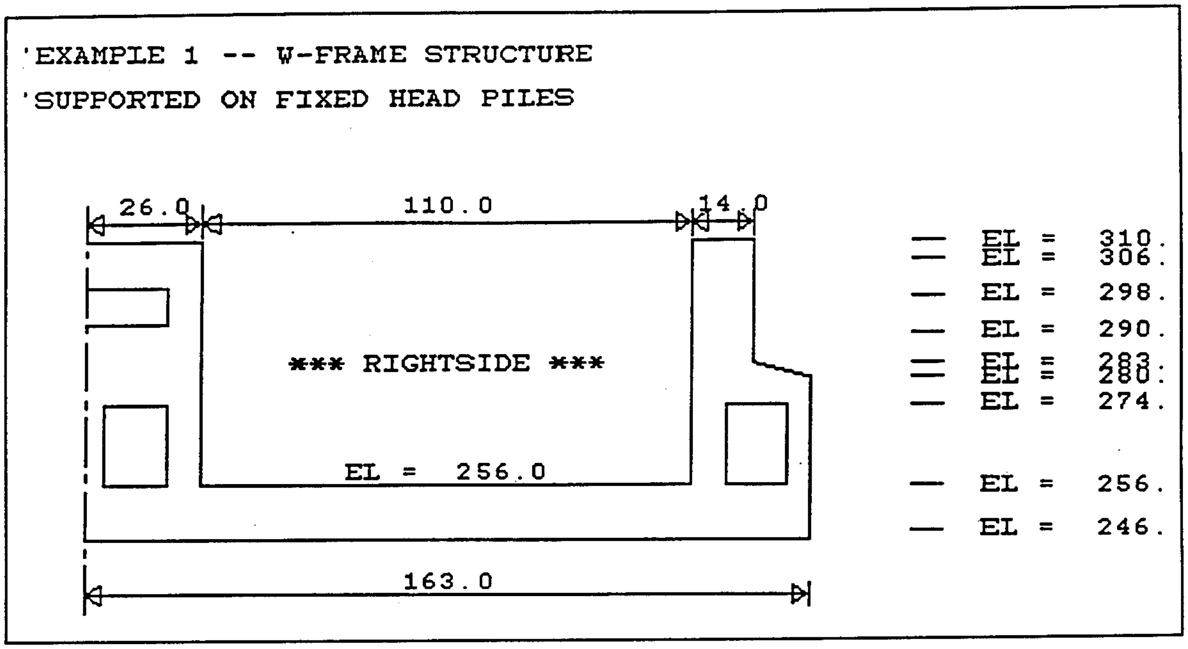


Figure 23. Graphical display of rightside structural geometry

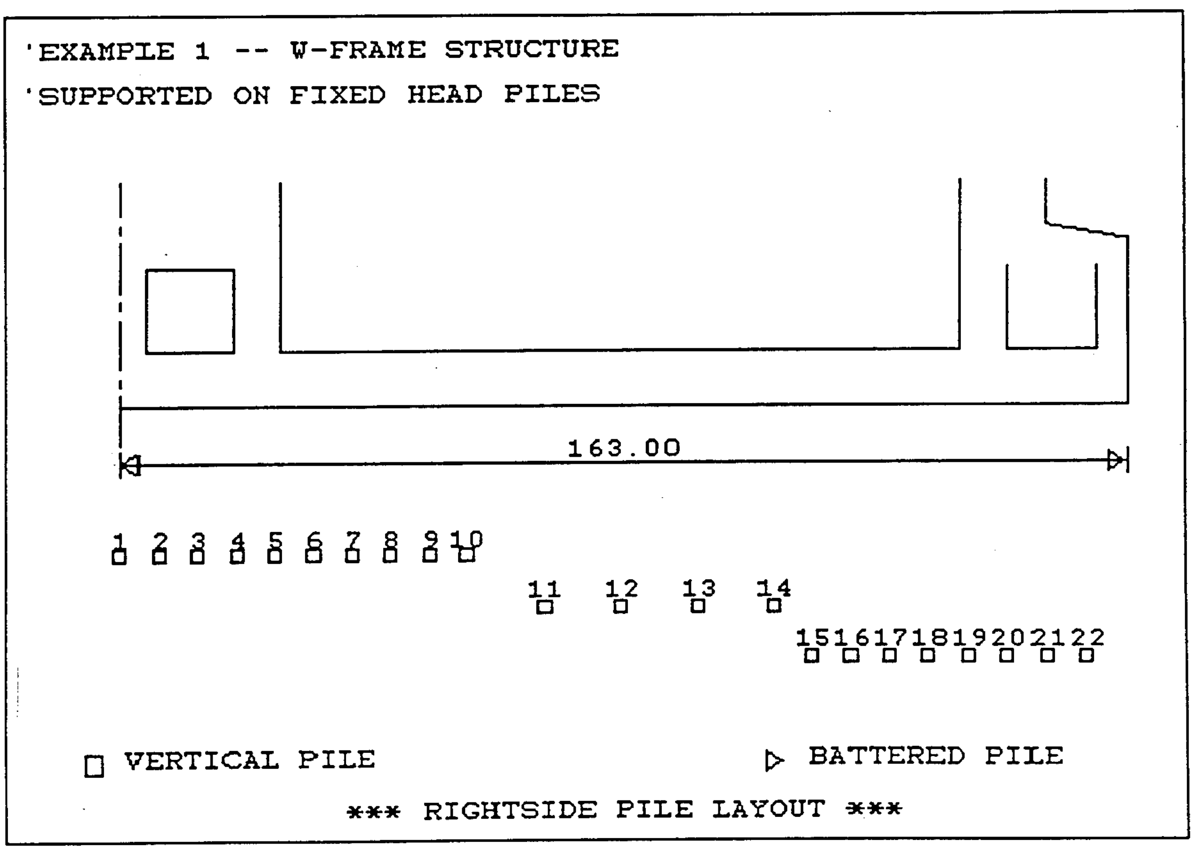


Figure 24. Graphical display of rightside pile layout

```
PROGRAM CDWFRM - DYNAMIC ANALYSIS OF TWO-DIMENSIONAL U/W-FRAME STRUCTURES
DATE 24-MAY-1994                                              TIME 11.35.15

I.--HEADING
  'EXAMPLE 1 -- W-FRAME STRUCTURE
  'SUPPORTED ON FIXED HEAD PILES

          ***********************
          *  FRAME MODEL DATA  *
          ***********************


 II.--RIGHTSIDE FRAME MODEL DATA

   II.A.--RIGID BLOCK DATA (FT) - TYPE E 2 MONOLITH
          (NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)

                   <--------------CORNER LOCATIONS-------------->
BLOCK  CORNER NO.     1       2       3       4       5       6      CENTROID
  1    X-COORD.    158.00  158.00  163.00  163.00  163.00  158.00     160.50
       ELEVATION   244.00  256.00  256.00  256.00  244.00  244.00     250.00
  2    X-COORD.    136.00  136.00  144.00  144.00  144.00  136.00     140.00
       ELEVATION   244.00  256.00  256.00  256.00  244.00  244.00     250.00
  3    X-COORD.    136.00  136.00  150.00  150.00  150.00  144.00     143.00
       ELEVATION   274.00  283.00  283.00  283.00  274.00  274.00     278.50
  4    X-COORD.    158.00  158.00  163.00  163.00  163.00  163.00     160.43
       ELEVATION   274.00  281.15  280.00  274.00  274.00  274.00     277.30
  6    X-COORD.    136.00  136.00  150.00  150.00  150.00  150.00     143.00
       ELEVATION   298.00  310.00  310.00  306.00  298.00  298.00     304.00

                                       II.B.--JOINT COORDINATES (FT)
          (NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)
          JOINT NO.        X-COORD.      ELEVATION
              1              .00000      250.00000
              2            31.25000      250.00000
              3            37.50000      250.00000
              4            43.75000      250.00000
              5            50.00000      250.00000
              6            56.25000      250.00000
              7            68.75000      250.00000
              8            81.25000      250.00000
              9            93.75000      250.00000
             10           106.25000      250.00000
             11           112.50000      250.00000
             12           118.75000      250.00000
             13           125.00000      250.00000
             14           131.25000      250.00000
             15           140.00000      250.00000
             16           150.00000      250.00000
             17           156.25000      250.00000
             18           160.50000      250.00000
             19           160.42690      277.29690
             20           143.00000      278.50000
             21           143.00000      290.00000
             22           143.00000      304.00000
   II.C.--MEMBER DATA (FT)
          (NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)
                         <COORDS AT ENDS OF FLEX LENGTH>
 MEM   FROM    TO        <--FROM END-->   <---TO END--->    <-MEMBER DEPTH-->
  NO    JT     JT           X     ELEV       X     ELEV     FROM END   TO END
  1      1      2        26.00  250.00    31.25  250.00      12.00     12.00
  2      2      3        31.25  250.00    37.50  250.00      12.00     12.00
  3      3      4        37.50  250.00    43.75  250.00      12.00     12.00
  4      4      5        43.75  250.00    50.00  250.00      12.00     12.00
  5      5      6        50.00  250.00    56.25  250.00      12.00     12.00
  6      6      7        56.25  250.00    68.75  250.00      12.00     12.00
  7      7      8        68.75  250.00    81.25  250.00      12.00     12.00
  8      8      9        81.25  250.00    93.75  250.00      12.00     12.00
  9      9     10        93.75  250.00   106.25  250.00      12.00     12.00
 10     10     11       106.25  250.00   112.50  250.00      12.00     12.00
 11     11     12       112.50  250.00   118.75  250.00      12.00     12.00
 12     12     13       118.75  250.00   125.00  250.00      12.00     12.00
 13     13     14       125.00  250.00   131.25  250.00      12.00     12.00
 14     14     15       131.25  250.00   136.00  250.00      12.00     12.00
 15     15     16       144.00  250.00   150.00  250.00      12.00     12.00
 16     16     17       150.00  250.00   156.25  250.00      12.00     12.00
 17     17     18       156.25  250.00   158.00  250.00      12.00     12.00
 18     18     19       160.50  256.00   160.50  274.00       5.00      5.00
 19     15     20       140.00  256.00   140.00  274.00       8.00      8.00
 20     20     19       150.00  278.50   158.00  277.58       9.00      7.15
 21     20     21       143.00  283.00   143.00  290.00      14.00     14.00
 22     21     22       143.00  290.00   143.00  298.00      14.00     14.00
```

Figure 25. Frame model data for example 1 (Sheet 1 of 3)

II.D.--PILE HEAD STIFFNESS COEFFICIENTS

PILE NO.	X-COORD. (FT)	BATTER (FT/FT)	B11 (LB/FT)	B22 (LB/FT)	B33 (LB-FT)	B13 (LB)
			<-------------STIFFNESS	COEFFICIENTS	------------->	
1	.00	.00	8.9222E+05	1.2636E+07	4.7580E+07	4.6071E+06
2	6.25	.00	8.9222E+05	1.2636E+07	4.7580E+07	4.6071E+06
3	12.50	.00	8.9222E+05	1.2636E+07	4.7580E+07	4.6071E+06
4	18.75	.00	8.9222E+05	1.2636E+07	4.7580E+07	4.6071E+06
5	25.00	.00	8.9222E+05	1.2636E+07	4.7580E+07	4.6071E+06
6	31.25	.00	8.9222E+05	1.2636E+07	4.7580E+07	4.6071E+06
7	37.50	.00	8.9222E+05	1.2636E+07	4.7580E+07	4.6071E+06
8	43.75	.00	8.9222E+05	1.2636E+07	4.7580E+07	4.6071E+06
9	50.00	.00	8.9222E+05	1.2636E+07	4.7580E+07	4.6071E+06
10	56.25	.00	8.9222E+05	1.2636E+07	4.7580E+07	4.6071E+06
11	68.75	.00	8.9222E+05	1.2636E+07	4.7580E+07	4.6071E+06
12	81.25	.00	8.9222E+05	1.2636E+07	4.7580E+07	4.6071E+06
13	93.75	.00	8.9222E+05	1.2636E+07	4.7580E+07	4.6071E+06
14	106.25	.00	8.9222E+05	1.2636E+07	4.7580E+07	4.6071E+06
15	112.50	.00	8.9222E+05	1.2636E+07	4.7580E+07	4.6071E+06
16	118.75	.00	8.9222E+05	1.2636E+07	4.7580E+07	4.6071E+06
17	125.00	.00	8.9222E+05	1.2636E+07	4.7580E+07	4.6071E+06
18	131.25	.00	8.9222E+05	1.2636E+07	4.7580E+07	4.6071E+06
19	137.50	.00	8.9222E+05	1.2636E+07	4.7580E+07	4.6071E+06
20	143.75	.00	8.9222E+05	1.2636E+07	4.7580E+07	4.6071E+06
21	150.00	.00	8.9222E+05	1.2636E+07	4.7580E+07	4.6071E+06
22	156.25	.00	8.9222E+05	1.2636E+07	4.7580E+07	4.6071E+06

III.-- LEFTSIDE FRAME MODEL DATA
SYMMETRIC WITH RIGHTSIDE

IV.--CENTER STEM MODEL DATA - TYPE C8 MONOLITH

IV.A.--RIGID BLOCK DATA (FT)
(NOTE: 'X-COORD.' IS DISTANCE FROM STRUCTURE CENTERLINE;
+ TO RIGHT, - TO LEFT.)

BLOCK 1:

CORNER NO.	X-COORD.	ELEVATION
1	-26.00	244.00
2	-26.00	256.00
3	-18.00	256.00
4	-18.00	256.00
5	-4.00	256.00
6	4.00	256.00
7	18.00	256.00
8	18.00	256.00
9	26.00	256.00
10	26.00	244.00
CENTROID	.00	250.00

BLOCK 2:

CORNER NO.	X-COORD.	ELEVATION
1	-26.00	274.00
2	-26.00	292.00
3	-18.00	292.00
4	18.00	292.00
5	26.00	292.00
6	26.00	274.00
7	18.00	274.00
8	4.00	274.00
9	-4.00	274.00
10	-18.00	274.00
CENTROID	.00	283.00

BLOCK 4:

CORNER NO.	X-COORD.	ELEVATION
1	18.00	300.00
2	18.00	310.00
3	26.00	310.00
4	26.00	300.00
CENTROID	22.00	305.00

BLOCK 5:

CORNER NO.	X-COORD.	ELEVATION
1	-26.00	300.00
2	-26.00	310.00
3	-18.00	310.00
4	-18.00	300.00
CENTROID	-22.00	305.00

Figure 25. (Sheet 2 of 3)

```
IV.B.--JOINT COORDINATES (FT)
        (NOTE: 'X-COORD.' IS DISTANCE FROM STRUCTURE CENTERLINE.)

   IV.B.1.--RIGHTSIDE JOINTS

        JOINT NO.          X-COORD.        ELEVATION
            1                .00000        250.00000
            2                .00000        283.00000
            3              22.00000        305.00000

   IV.B.2.--LEFTSIDE JOINTS
        SYMMETRIC WITH RIGHTSIDE

IV.C.--MEMBER DATA (FT)
        (NOTE: 'XCOORD.' IS DISTANCE FROM STRUCTURE CENTERLINE.)

   IV.C.1.--RIGHTSIDE MEMBERS

                          <COORDS AT ENDS OF FLEX LENGTH>
MEM  FROM    TO           <--FROM END-->    <---TO END--->     <-MEMBER DEPTH-->
NO    JT     JT             X      ELEV        X      ELEV
 1    R1     R2           22.00  256.00      22.00  274.00           8.00
 2    R2     R3           22.00  292.00      22.00  300.00           8.00

   IV.C.2.--LEFTSIDE MEMBERS
        SYMMETRIC WITH RIGHTSIDE

   IV.C.3.--MEMBERS ON OR CROSSING STRUCTURE CENTERLINE.

                          <COORDS AT ENDS OF FLEX LENGTH>
MEM  FROM    TO           <--FROM END-->    <---TO END--->     <-MEMBER DEPTH-->
NO    JT     JT             X      ELEV        X      ELEV
 1    R1     R2             .00  256.00        .00  274.00           8.00
 3    L3     R3          -18.00  305.00      18.00  305.00          10.00
```

Figure 25. (Sheet 3 of 3)

```
PROGRAM CDWFRM - DYNAMIC ANALYSIS OF TWO-DIMENSIONAL U/W-FRAME STRUCTURES
DATE 24-MAY-1994                                               TIME 11.38.39

I.--HEADING
  'EXAMPLE 1 -- W-FRAME STRUCTURE
  'SUPPORTED ON FIXED HEAD PILES

     ****************************************************
     *  RESULTS FOR MODE  1 (FREQUENCY = 1.959E+00 HZ)  *
     ****************************************************

II.--STRUCTURE DISPLACEMENTS
     (POSITIVE HORIZONTAL DISPLACEMENT IS TO THE RIGHT.)
     (POSITIVE VERTICAL DISPLACEMENT IS UP.)
     (POSITIVE ROTATION IS COUNTERCLOCKWISE.)

  II.A.--RIGHTSIDE DISPLACEMENTS - TYPE E 2 MONOLITH

JT   DISTANCE FROM   ELEVATION   <----DISPLACEMENT (FT OR RADIANS)---->
NO   STRUC CL (FT)     (FT)       HORIZONTAL    VERTICAL        ROTATION
                         ***** BASE JOINTS *****
 1            .00      250.00     6.962E-01    1.356E-14      -1.092E-03
 2          31.25      250.00     6.960E-01   -3.135E-02      -5.281E-04
 3          37.50      250.00     6.957E-01   -3.160E-02       2.077E-06
 4          43.75      250.00     6.956E-01   -2.913E-02       4.027E-04
 5          50.00      250.00     6.955E-01   -2.463E-02       7.063E-04
 6          56.25      250.00     6.954E-01   -1.860E-02       9.415E-04
 7          68.75      250.00     6.954E-01   -3.333E-03       1.189E-03
 8          81.25      250.00     6.955E-01    1.293E-02       1.109E-03
 9          93.75      250.00     6.956E-01    2.622E-02       6.818E-04
10         106.25      250.00     6.957E-01    3.188E-02      -1.747E-04
11         112.50      250.00     6.958E-01    3.007E-02      -7.776E-04
12         118.75      250.00     6.960E-01    2.429E-02      -1.505E-03
13         125.00      250.00     6.963E-01    1.364E-02      -2.385E-03
14         131.25      250.00     6.966E-01   -2.978E-03      -3.441E-03
15         140.00      250.00     6.968E-01   -3.778E-02      -4.357E-03
16         150.00      250.00     6.968E-01   -8.335E-02      -4.932E-03
17         156.25      250.00     6.969E-01   -1.163E-01      -5.354E-03
18         160.50      250.00     6.969E-01   -1.396E-01      -5.420E-03

                         ***** STEM JOINTS *****
19         160.43      277.30     8.459E-01   -1.426E-01      -4.881E-03
20         143.00      278.50     8.519E-01   -5.266E-02      -5.606E-03
21         143.00      290.00     9.176E-01   -5.267E-02      -5.777E-03
22         143.00      304.00     1.000E+00   -5.268E-02      -5.871E-03
```

Figure 26. Structural response for mode 1 (Sheet 1 of 6)

II.B.-- LEFTSIDE DISPLACEMENTS - TYPE E 2 MONOLITH

JT NO	DISTANCE FROM STRUC CL (FT)	ELEVATION (FT)	<----DISPLACEMENT (FT OR RADIANS)----> HORIZONTAL	VERTICAL	ROTATION
		***** BASE JOINTS *****			
1	.00	250.00	6.962E-01	1.356E-14	-1.092E-03
2	31.25	250.00	6.960E-01	3.135E-02	-5.281E-04
3	37.50	250.00	6.957E-01	3.160E-02	2.077E-06
4	43.75	250.00	6.956E-01	2.913E-02	4.027E-04
5	50.00	250.00	6.955E-01	2.463E-02	7.063E-04
6	56.25	250.00	6.954E-01	1.860E-02	9.415E-04
7	68.75	250.00	6.954E-01	3.333E-03	1.189E-03
8	81.25	250.00	6.955E-01	-1.293E-02	1.109E-03
9	93.75	250.00	6.956E-01	-2.622E-02	6.818E-04
10	106.25	250.00	6.957E-01	-3.188E-02	-1.747E-04
11	112.50	250.00	6.958E-01	-3.007E-02	-7.776E-04
12	118.75	250.00	6.960E-01	-2.429E-02	-1.505E-03
13	125.00	250.00	6.963E-01	-1.364E-02	-2.385E-03
14	131.25	250.00	6.966E-01	2.978E-03	-3.441E-03
15	140.00	250.00	6.968E-01	3.778E-02	-4.357E-03
16	150.00	250.00	6.968E-01	8.335E-02	-4.932E-03
17	156.25	250.00	6.969E-01	1.163E-01	-5.354E-03
18	160.50	250.00	6.969E-01	1.396E-01	-5.420E-03
		***** STEM JOINTS *****			
19	160.43	277.30	8.459E-01	1.426E-01	-4.881E-03
20	143.00	278.50	8.519E-01	5.266E-02	-5.606E-03
21	143.00	290.00	9.176E-01	5.267E-02	-5.777E-03
22	143.00	304.00	1.000E+00	5.268E-02	-5.871E-03

II.C.--CENTER STEM DISPLACEMENTS - TYPE C8 MONOLITH

II.C.1.--RIGHTSIDE CENTER STEM JOINTS

JT NO	DISTANCE FROM STRUC CL (FT)	ELEVATION (FT)	<----DISPLACEMENT (FT OR RADIANS)----> HORIZONTAL	VERTICAL	ROTATION
1	.00	250.00	6.962E-01	1.356E-14	-1.092E-03
2	.00	283.00	7.457E-01	1.427E-14	-1.202E-03
3	22.00	305.00	7.745E-01	-2.654E-02	-1.326E-03

II.C.2.-- LEFTSIDE CENTER STEM JOINTS

JT NO	DISTANCE FROM STRUC CL (FT)	ELEVATION (FT)	<----DISPLACEMENT (FT OR RADIANS)----> HORIZONTAL	VERTICAL	ROTATION
1	.00	250.00	6.962E-01	1.356E-14	-1.092E-03
2	.00	283.00	7.457E-01	1.427E-14	-1.202E-03
3	22.00	305.00	7.745E-01	2.654E-02	-1.326E-03

Figure 26. (Sheet 2 of 6)

III.--FORCES AT ENDS OF MEMBERS

(MEMBER FORCES ARE GIVEN AT ENDS OF FLEXIBLE LENGTH.)
(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR FORCE IN TENDS TO MOVE THE LEFT END OF A HORIZONTAL MEMBER UPWARD.)
(POSITIVE SHEAR FORCE IN TENDS TO MOVE THE LOWER END OF A VERTICAL MEMBER TO THE LEFT.)
(POSITIVE MOMENT PRODUCES COMPRESSION ON THE TOP OR ON THE LEFT FACE OF A MEMBER.)

III.A.--RIGHTSIDE MEMBERS - TYPE E 2 MONOLITH

MEM NO	DISTANCE FROM STRUC CL (FT)	ELEVATION (FT)	<--------FORCES (LB OR LB-FT)--------> AXIAL	SHEAR	MOMENT
		***** BASE MEMBERS *****			
1	26.00	250.00	1.814E+06	-3.209E+06	5.768E+07
	31.25	250.00	1.814E+06	-3.209E+06	4.083E+07
2	31.25	250.00	1.418E+06	-2.823E+06	4.770E+07
	37.50	250.00	1.418E+06	-2.823E+06	3.005E+07
3	37.50	250.00	1.037E+06	-2.435E+06	3.698E+07
	43.75	250.00	1.037E+06	-2.435E+06	2.177E+07
4	43.75	250.00	6.520E+05	-2.077E+06	2.875E+07
	50.00	250.00	6.520E+05	-2.077E+06	1.577E+07
5	50.00	250.00	2.638E+05	-1.774E+06	2.279E+07
	56.25	250.00	2.638E+05	-1.774E+06	1.170E+07
6	56.25	250.00	-6.919E+03	-1.548E+06	1.876E+07
	68.75	250.00	-6.919E+03	-1.548E+06	-5.848E+05
7	68.75	250.00	-1.604E+05	-1.508E+06	6.493E+06
	81.25	250.00	-1.604E+05	-1.508E+06	-1.236E+07
8	81.25	250.00	-3.132E+05	-1.662E+06	-5.288E+06
	93.75	250.00	-3.132E+05	-1.662E+06	-2.607E+07
9	93.75	250.00	-4.617E+05	-1.976E+06	-1.905E+07
	106.25	250.00	-4.617E+05	-1.976E+06	-4.375E+07
10	106.25	250.00	-7.215E+05	-2.362E+06	-3.683E+07
	112.50	250.00	-7.215E+05	-2.362E+06	-5.159E+07
11	112.50	250.00	-1.095E+06	-2.731E+06	-4.476E+07
	118.75	250.00	-1.095E+06	-2.731E+06	-6.183E+07
12	118.75	250.00	-1.461E+06	-3.029E+06	-5.510E+07
	125.00	250.00	-1.461E+06	-3.029E+06	-7.403E+07
13	125.00	250.00	-1.819E+06	-3.197E+06	-6.742E+07
	131.25	250.00	-1.819E+06	-3.197E+06	-8.740E+07
14	131.25	250.00	-2.195E+06	-3.159E+06	-8.092E+07
	136.00	250.00	-2.195E+06	-3.159E+06	-9.592E+07
15	144.00	250.00	-5.940E+04	5.669E+05	-4.561E+07
	150.00	250.00	-5.940E+04	5.669E+05	-4.221E+07
16	150.00	250.00	-3.969E+05	1.592E+06	-3.593E+07
	156.25	250.00	-3.969E+05	1.592E+06	-2.598E+07
17	156.25	250.00	-8.118E+05	3.038E+06	-1.978E+07
	158.00	250.00	-8.118E+05	3.038E+06	-1.446E+07

Figure 26. (Sheet 3 of 6)

***** CULVER

18	160.50	256.00	2.961E+06	4.296E+05	-2.875E+06
	160.50	274.00	2.961E+06	4.296E+05	4.858E+06
19	140.00	256.00	-2.743E+06	2.532E+06	-3.221E+07
	140.00	274.00	-2.743E+06	2.532E+06	1.337E+07
20	150.00	278.50	3.459E+05	-2.871E+06	2.512E+07
	158.00	277.58	3.459E+05	-2.871E+06	1.999E+06
		***** STEM MEMBERS *****			
21	143.00	283.00	7.955E+04	1.465E+06	-2.294E+07
	143.00	290.00	7.955E+04	1.465E+06	-1.269E+07
22	143.00	290.00	5.416E+04	1.022E+06	-1.260E+07
	143.00	298.00	5.416E+04	1.022E+06	-4.431E+06

III.B.-- LEFTSIDE MEMBERS - TYPE E 2 MONOLITH

MEM NO	DISTANCE FROM STRUC CL (FT)	ELEVATION (FT)	<--------FORCES (LB OR LB-FT)--------> AXIAL	SHEAR	MOMENT
		***** BASE MEMBERS *****			
1	26.00	250.00	-1.814E+06	-3.209E+06	-5.768E+07
	31.25	250.00	-1.814E+06	-3.209E+06	-4.083E+07
2	31.25	250.00	-1.418E+06	-2.823E+06	-4.770E+07
	37.50	250.00	-1.418E+06	-2.823E+06	-3.005E+07
3	37.50	250.00	-1.037E+06	-2.435E+06	-3.698E+07
	43.75	250.00	-1.037E+06	-2.435E+06	-2.177E+07
4	43.75	250.00	-6.520E+05	-2.077E+06	-2.875E+07
	50.00	250.00	-6.520E+05	-2.077E+06	-1.577E+07
5	50.00	250.00	-2.638E+05	-1.774E+06	-2.279E+07
	56.25	250.00	-2.638E+05	-1.774E+06	-1.170E+07
6	56.25	250.00	6.919E+03	-1.548E+06	-1.876E+07
	68.75	250.00	6.919E+03	-1.548E+06	5.848E+05
7	68.75	250.00	1.604E+05	-1.508E+06	-6.493E+06
	81.25	250.00	1.604E+05	-1.508E+06	1.236E+07
8	81.25	250.00	3.132E+05	-1.662E+06	5.288E+06
	93.75	250.00	3.132E+05	-1.662E+06	2.607E+07
9	93.75	250.00	4.617E+05	-1.976E+06	1.905E+07
	106.25	250.00	4.617E+05	-1.976E+06	4.375E+07
10	106.25	250.00	7.215E+05	-2.362E+06	3.683E+07
	112.50	250.00	7.215E+05	-2.362E+06	5.159E+07
11	112.50	250.00	1.095E+06	-2.731E+06	4.476E+07
	118.75	250.00	1.095E+06	-2.731E+06	6.183E+07
12	118.75	250.00	1.461E+06	-3.029E+06	5.510E+07
	125.00	250.00	1.461E+06	-3.029E+06	7.403E+07
13	125.00	250.00	1.819E+06	-3.197E+06	6.742E+07
	131.25	250.00	1.819E+06	-3.197E+06	8.740E+07
14	131.25	250.00	2.195E+06	-3.159E+06	8.092E+07
	136.00	250.00	2.195E+06	-3.159E+06	9.592E+07
15	144.00	250.00	5.940E+04	5.669E+05	4.561E+07
	150.00	250.00	5.940E+04	5.669E+05	4.221E+07
16	150.00	250.00	3.969E+05	1.592E+06	3.593E+07
	156.25	250.00	3.969E+05	1.592E+06	2.598E+07
17	156.25	250.00	8.118E+05	3.038E+06	1.978E+07
	158.00	250.00	8.118E+05	3.038E+06	1.446E+07

Figure 26. (Sheet 4 of 6)

		***** CULVERT MEMBERS *****			
18	160.50	256.00	-2.961E+06	4.296E+05	-2.875E+06
	160.50	274.00	-2.961E+06	4.296E+05	4.858E+06
19	140.00	256.00	2.743E+06	2.532E+06	-3.221E+07
	140.00	274.00	2.743E+06	2.532E+06	1.337E+07
20	150.00	278.50	-3.459E+05	-2.871E+06	-2.512E+07
	158.00	277.58	-3.459E+05	-2.871E+06	-1.999E+06
		***** STEM MEMBERS *****			
21	143.00	283.00	-7.955E+04	1.465E+06	-2.294E+07
	143.00	290.00	-7.955E+04	1.465E+06	-1.269E+07
22	143.00	290.00	-5.416E+04	1.022E+06	-1.260E+07
	143.00	298.00	-5.416E+04	1.022E+06	-4.431E+06

III.C.--CENTER STEM MEMBERS - TYPE C8 MONOLITH

III.C.1.--RIGHTSIDE CENTER STEM MEMBERS

MEM NO	DISTANCE FROM STRUC CL (FT)	ELEVATION (FT)	<--------FORCES (LB OR LB-FT)--------> AXIAL	SHEAR	MOMENT
1	22.00	256.00	3.410E+06	2.073E+06	-1.949E+07
	22.00	274.00	3.410E+06	2.073E+06	1.783E+07
2	22.00	292.00	3.154E+05	1.037E+06	-6.244E+06
	22.00	300.00	3.154E+05	1.037E+06	2.050E+06

III.C.2.-- LEFTSIDE CENTER STEM MEMBERS

MEM NO	DISTANCE FROM STRUC CL (FT)	ELEVATION (FT)	<--------FORCES (LB OR LB-FT)--------> AXIAL	SHEAR	MOMENT
1	22.00	256.00	-3.410E+06	2.073E+06	-1.949E+07
	22.00	274.00	-3.410E+06	2.073E+06	1.783E+07
2	22.00	292.00	-3.154E+05	1.037E+06	-6.244E+06
	22.00	300.00	-3.154E+05	1.037E+06	2.050E+06

III.C.3.--MEMBERS ON OR CROSSING STRUCTURE CENTERLINE

MEM NO	DISTANCE FROM STRUC CL (FT)	ELEVATION (FT)	<--------FORCES (LB OR LB-FT)--------> AXIAL	SHEAR	MOMENT
1	.00	256.00	-1.003E-06	2.073E+06	-1.949E+07
	.00	274.00	-1.003E-06	2.073E+06	1.783E+07
3	-18.00	305.00	7.899E-07	-2.945E+05	5.301E+06
	18.00	305.00	7.899E-07	-2.945E+05	-5.301E+06

Figure 26. (Sheet 5 of 6)

IV.--PILE HEAD FORCES
(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR FORCE TENDS TO MOVE THE PILE HEAD TO THE RIGHT.)
(POSITIVE MOMENT PRODUCES COMPRESSION ON THE LEFT SIDE OF THE PILE.)

IV.A.--RIGHTSIDE PILE HEAD FORCES

PILE NO.	DISTANCE FROM STRUC CL (FT)	<--------FORCES (LB OR LB-FT)---------> AXIAL	SHEAR	MOMENT
1	.00	0.000E+00	6.103E+05	3.125E+06
2	6.25	8.627E+04	6.103E+05	3.125E+06
3	12.50	1.725E+05	6.103E+05	3.125E+06
4	18.75	2.588E+05	6.103E+05	3.125E+06
5	25.00	3.451E+05	6.103E+05	3.125E+06
6	31.25	3.962E+05	6.157E+05	3.167E+06
7	37.50	3.993E+05	6.208E+05	3.205E+06
8	43.75	3.680E+05	6.246E+05	3.235E+06
9	50.00	3.112E+05	6.275E+05	3.257E+06
10	56.25	2.350E+05	6.298E+05	3.275E+06
11	68.75	4.212E+04	6.323E+05	3.293E+06
12	81.25	-1.634E+05	6.316E+05	3.288E+06
13	93.75	-3.313E+05	6.274E+05	3.256E+06
14	106.25	-4.028E+05	6.190E+05	3.192E+06
15	112.50	-3.800E+05	6.131E+05	3.147E+06
16	118.75	-3.070E+05	6.060E+05	3.093E+06
17	125.00	-1.724E+05	5.975E+05	3.028E+06
18	131.25	3.763E+04	5.872E+05	2.950E+06
19	137.50	3.398E+05	5.783E+05	2.883E+06
20	143.75	6.839E+05	5.783E+05	2.883E+06
21	150.00	1.053E+06	5.726E+05	2.839E+06
22	156.25	1.469E+06	5.685E+05	2.808E+06

IV.B.-- LEFTSIDE PILE HEAD FORCES

PILE NO.	DISTANCE FROM STRUC CL (FT)	<---------FORCES (LB OR LB-FT)---------> AXIAL	SHEAR	MOMENT
1	.00	0.000E+00	6.103E+05	3.125E+06
2	6.25	8.627E+04	6.103E+05	3.125E+06
3	12.50	1.725E+05	6.103E+05	3.125E+06
4	18.75	2.588E+05	6.103E+05	3.125E+06
5	25.00	3.451E+05	6.103E+05	3.125E+06
6	31.25	3.962E+05	6.157E+05	3.167E+06
7	37.50	3.993E+05	6.208E+05	3.205E+06
8	43.75	3.680E+05	6.246E+05	3.235E+06
9	50.00	3.112E+05	6.275E+05	3.257E+06
10	56.25	2.350E+05	6.298E+05	3.275E+06
11	68.75	4.212E+04	6.323E+05	3.293E+06
12	81.25	-1.634E+05	6.316E+05	3.288E+06
13	93.75	-3.313E+05	6.274E+05	3.256E+06
14	106.25	-4.028E+05	6.190E+05	3.192E+06
15	112.50	-3.800E+05	6.131E+05	3.147E+06
16	118.75	-3.070E+05	6.060E+05	3.093E+06
17	125.00	-1.724E+05	5.975E+05	3.028E+06
18	131.25	3.763E+04	5.872E+05	2.950E+06
19	137.50	3.398E+05	5.783E+05	2.883E+06
20	143.75	6.839E+05	5.783E+05	2.883E+06
21	150.00	1.053E+06	5.726E+05	2.839E+06
22	156.25	1.469E+06	5.685E+05	2.808E+06

Figure 26. (Sheet 6 of 6)

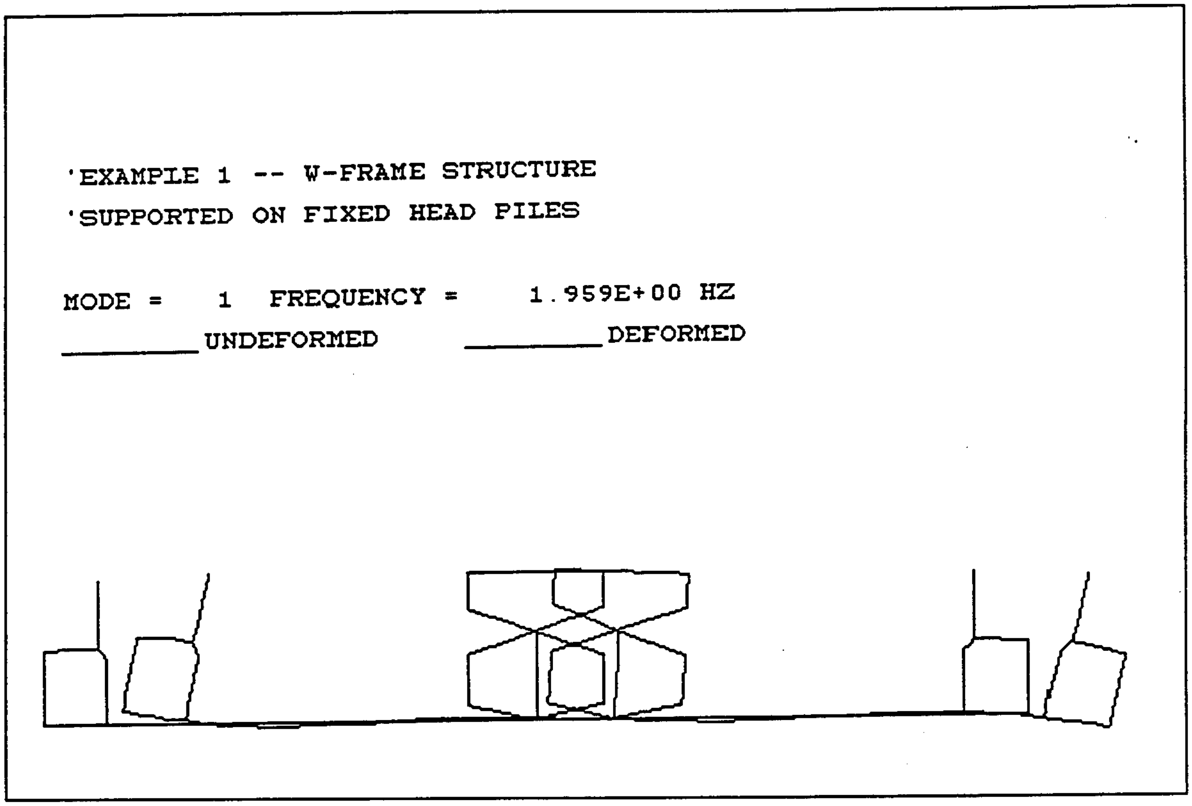


Figure 27. Deformed structure for mode 1

PROGRAM CDWFRM - DYNAMIC ANALYSIS OF TWO-DIMENSIONAL U/W-FRAME STRUCTURES
DATE 24-MAY-1994 TIME 11.39.12

I.--HEADING
'EXAMPLE 1 -- W-FRAME STRUCTURE
'SUPPORTED ON FIXED HEAD PILES

```
**********************************************
*  RESULTS OF COMPLETE QUADRATIC COMBINATION  *
*             OF MODES 1 THROUGH 50           *
**********************************************
```

II.--MAXIMUM STRUCTURE DISPLACEMENTS

II.A.--RIGHTSIDE DISPLACEMENTS - TYPE E 2 MONOLITH

JT NO	DISTANCE FROM STRUC CL (FT)	ELEVATION (FT)	<----DISPLACEMENT (FT OR RADIANS)----> HORIZONTAL	VERTICAL	ROTATION
		***** BASE JOINTS *****			
1	.00	250.00	1.753E-01	3.479E-15	2.839E-04
2	31.25	250.00	1.753E-01	8.165E-03	1.406E-04
3	37.50	250.00	1.752E-01	8.268E-03	2.530E-05
4	43.75	250.00	1.752E-01	7.691E-03	1.030E-04
5	50.00	250.00	1.751E-01	6.626E-03	1.789E-04
6	56.25	250.00	1.751E-01	5.229E-03	2.382E-04
7	68.75	250.00	1.751E-01	2.437E-03	3.007E-04
8	81.25	250.00	1.751E-01	4.034E-03	2.804E-04
9	93.75	250.00	1.752E-01	7.033E-03	1.731E-04
10	106.25	250.00	1.752E-01	8.324E-03	6.390E-05
11	112.50	250.00	1.752E-01	7.815E-03	2.090E-04
12	118.75	250.00	1.753E-01	6.307E-03	3.942E-04
13	125.00	250.00	1.753E-01	3.609E-03	6.201E-04
14	131.25	250.00	1.754E-01	1.485E-03	8.915E-04
15	140.00	250.00	1.755E-01	9.991E-03	1.128E-03
16	150.00	250.00	1.755E-01	2.175E-02	1.276E-03
17	156.25	250.00	1.755E-01	3.026E-02	1.385E-03
18	160.50	250.00	1.755E-01	3.630E-02	1.402E-03
		***** STEM JOINTS *****			
19	160.43	277.30	2.131E-01	3.708E-02	1.263E-03
20	143.00	278.50	2.146E-01	1.383E-02	1.452E-03
21	143.00	290.00	2.314E-01	1.384E-02	1.497E-03
22	143.00	304.00	2.524E-01	1.384E-02	1.522E-03

Figure 28. Results of complete quadratic combination (Sheet 1 of 6)

II.B.-- LEFTSIDE DISPLACEMENTS - TYPE E 2 MONOLITH

JT NO	DISTANCE FROM STRUC CL (FT)	ELEVATION (FT)	<----DISPLACEMENT (FT OR RADIANS)----> HORIZONTAL	VERTICAL	ROTATION
		***** BASE JOINTS *****			
1	.00	250.00	1.753E-01	3.479E-15	2.839E-04
2	31.25	250.00	1.753E-01	8.165E-03	1.406E-04
3	37.50	250.00	1.752E-01	8.268E-03	2.530E-05
4	43.75	250.00	1.752E-01	7.691E-03	1.030E-04
5	50.00	250.00	1.751E-01	6.626E-03	1.789E-04
6	56.25	250.00	1.751E-01	5.229E-03	2.382E-04
7	68.75	250.00	1.751E-01	2.437E-03	3.007E-04
8	81.25	250.00	1.751E-01	4.034E-03	2.804E-04
9	93.75	250.00	1.752E-01	7.033E-03	1.731E-04
10	106.25	250.00	1.752E-01	8.324E-03	6.390E-05
11	112.50	250.00	1.752E-01	7.815E-03	2.090E-04
12	118.75	250.00	1.753E-01	6.307E-03	3.942E-04
13	125.00	250.00	1.753E-01	3.609E-03	6.201E-04
14	131.25	250.00	1.754E-01	1.485E-03	8.915E-04
15	140.00	250.00	1.755E-01	9.991E-03	1.128E-03
16	150.00	250.00	1.755E-01	2.175E-02	1.276E-03
17	156.25	250.00	1.755E-01	3.026E-02	1.385E-03
18	160.50	250.00	1.755E-01	3.630E-02	1.402E-03
		***** STEM JOINTS *****			
19	160.43	277.30	2.131E-01	3.708E-02	1.263E-03
20	143.00	278.50	2.146E-01	1.383E-02	1.452E-03
21	143.00	290.00	2.314E-01	1.384E-02	1.497E-03
22	143.00	304.00	2.524E-01	1.384E-02	1.522E-03

II.C.--CENTER STEM DISPLACEMENTS - TYPE C8 MONOLITH

II.C.1.--RIGHTSIDE CENTER STEM JOINTS

JT NO	DISTANCE FROM STRUC CL (FT)	ELEVATION (FT)	<----DISPLACEMENT (FT OR RADIANS)----> HORIZONTAL	VERTICAL	ROTATION
1	.00	250.00	1.753E-01	3.479E-15	2.839E-04
2	.00	283.00	3.122E-04	3.122E-04	3.122E-04
3	22.00	305.00	3.122E-04	3.122E-04	3.122E-04

II.C.2.-- LEFTSIDE CENTER STEM JOINTS

JT NO	DISTANCE FROM STRUC CL (FT)	ELEVATION (FT)	<----DISPLACEMENT (FT OR RADIANS)----> HORIZONTAL	VERTICAL	ROTATION
1	.00	250.00	1.753E-01	3.479E-15	2.839E-04
2	.00	283.00	3.122E-04	3.122E-04	3.122E-04
3	22.00	305.00	3.122E-04	3.122E-04	3.122E-04

Figure 28. (Sheet 2 of 6)

III.--MAXIMUM FORCES AT ENDS OF MEMBERS
(MEMBER FORCES ARE GIVEN AT ENDS OF FLEXIBLE LENGTH.)

III.A.--RIGHTSIDE MEMBERS - TYPE E 2 MONOLITH

MEM NO	DISTANCE FROM STRUC CL (FT)	ELEVATION (FT)	<--------FORCES (LB OR LB-FT)--------> AXIAL	SHEAR	MOMENT
		***** BASE MEMBERS *****			
1	26.00	250.00	4.578E+05	8.100E+05	1.456E+07
	31.25	250.00	4.578E+05	8.100E+05	1.031E+07
2	31.25	250.00	3.581E+05	7.126E+05	1.204E+07
	37.50	250.00	3.581E+05	7.126E+05	7.587E+06
3	37.50	250.00	2.618E+05	6.146E+05	9.336E+06
	43.75	250.00	2.618E+05	6.146E+05	5.495E+06
4	43.75	250.00	1.646E+05	5.242E+05	7.257E+06
	50.00	250.00	1.646E+05	5.242E+05	3.981E+06
5	50.00	250.00	6.660E+04	4.479E+05	5.753E+06
	56.25	250.00	6.660E+04	4.479E+05	2.954E+06
6	56.25	250.00	1.746E+03	3.907E+05	4.736E+06
	68.75	250.00	1.746E+03	3.907E+05	1.476E+05
7	68.75	250.00	4.050E+04	3.807E+05	1.639E+06
	81.25	250.00	4.050E+04	3.807E+05	3.119E+06
8	81.25	250.00	7.906E+04	4.197E+05	1.335E+06
	93.75	250.00	7.906E+04	4.197E+05	6.581E+06
9	93.75	250.00	1.165E+05	4.987E+05	4.810E+06
	106.25	250.00	1.165E+05	4.987E+05	1.104E+07
10	106.25	250.00	1.821E+05	5.962E+05	9.296E+06
	112.50	250.00	1.821E+05	5.962E+05	1.302E+07
11	112.50	250.00	2.764E+05	6.894E+05	1.130E+07
	118.75	250.00	2.764E+05	6.894E+05	1.561E+07
12	118.75	250.00	3.689E+05	7.647E+05	1.391E+07
	125.00	250.00	3.689E+05	7.647E+05	1.869E+07
13	125.00	250.00	4.592E+05	8.069E+05	1.702E+07
	131.25	250.00	4.592E+05	8.069E+05	2.206E+07
14	131.25	250.00	5.542E+05	7.974E+05	2.043E+07
	136.00	250.00	5.542E+05	7.974E+05	2.421E+07
15	144.00	250.00	1.499E+04	1.431E+05	1.151E+07
	150.00	250.00	1.499E+04	1.431E+05	1.066E+07
16	150.00	250.00	1.002E+05	4.019E+05	9.070E+06
	156.25	250.00	1.002E+05	4.019E+05	6.558E+06
17	156.25	250.00	2.049E+05	7.668E+05	4.992E+06
	158.00	250.00	2.049E+05	7.668E+05	3.650E+06

Figure 28. (Sheet 3 of 6)

					***** CULVER
18	160.50	256.00	7.474E+05	1.085E+05	7.258E+05
	160.50	274.00	7.474E+05	1.085E+05	1.226E+06
19	140.00	256.00	6.923E+05	6.392E+05	8.130E+06
	140.00	274.00	6.923E+05	6.392E+05	3.376E+06
20	150.00	278.50	8.731E+04	7.247E+05	6.341E+06
	158.00	277.58	8.731E+04	7.247E+05	5.047E+05
		***** STEM MEMBERS *****			
21	143.00	283.00	2.008E+04	3.697E+05	5.791E+06
	143.00	290.00	2.008E+04	3.697E+05	3.203E+06
22	143.00	290.00	1.367E+04	2.579E+05	3.182E+06
	143.00	298.00	1.367E+04	2.579E+05	1.118E+06

III.B.-- LEFTSIDE MEMBERS - TYPE E 2 MONOLITH

MEM NO	DISTANCE FROM STRUC CL (FT)	ELEVATION (FT)	<--------FORCES (LB OR LB-FT)--------> AXIAL	SHEAR	MOMENT
		***** BASE MEMBERS *****			
1	26.00	250.00	4.578E+05	8.100E+05	1.456E+07
	31.25	250.00	4.578E+05	8.100E+05	1.031E+07
2	31.25	250.00	3.581E+05	7.126E+05	1.204E+07
	37.50	250.00	3.581E+05	7.126E+05	7.587E+06
3	37.50	250.00	2.618E+05	6.146E+05	9.336E+06
	43.75	250.00	2.618E+05	6.146E+05	5.495E+06
4	43.75	250.00	1.646E+05	5.242E+05	7.257E+06
	50.00	250.00	1.646E+05	5.242E+05	3.981E+06
5	50.00	250.00	6.660E+04	4.479E+05	5.753E+06
	56.25	250.00	6.660E+04	4.479E+05	2.954E+06
6	56.25	250.00	1.746E+03	3.907E+05	4.736E+06
	68.75	250.00	1.746E+03	3.907E+05	1.476E+05
7	68.75	250.00	4.050E+04	3.807E+05	1.639E+06
	81.25	250.00	4.050E+04	3.807E+05	3.119E+06
8	81.25	250.00	7.906E+04	4.197E+05	1.335E+06
	93.75	250.00	7.906E+04	4.197E+05	6.581E+06
9	93.75	250.00	1.165E+05	4.987E+05	4.810E+06
	106.25	250.00	1.165E+05	4.987E+05	1.104E+07
10	106.25	250.00	1.821E+05	5.962E+05	9.296E+06
	112.50	250.00	1.821E+05	5.962E+05	1.302E+07
11	112.50	250.00	2.764E+05	6.894E+05	1.130E+07
	118.75	250.00	2.764E+05	6.894E+05	1.561E+07
12	118.75	250.00	3.689E+05	7.647E+05	1.391E+07
	125.00	250.00	3.689E+05	7.647E+05	1.869E+07
13	125.00	250.00	4.592E+05	8.069E+05	1.702E+07
	131.25	250.00	4.592E+05	8.069E+05	2.206E+07
14	131.25	250.00	5.542E+05	7.974E+05	2.043E+07
	136.00	250.00	5.542E+05	7.974E+05	2.421E+07
15	144.00	250.00	1.499E+04	1.431E+05	1.151E+07
	150.00	250.00	1.499E+04	1.431E+05	1.066E+07
16	150.00	250.00	1.002E+05	4.019E+05	9.070E+06
	156.25	250.00	1.002E+05	4.019E+05	6.558E+06
17	156.25	250.00	2.049E+05	7.668E+05	4.992E+06
	158.00	250.00	2.049E+05	7.668E+05	3.650E+06

Figure 28. (Sheet 4 of 6)

		***** CULVERT MEMBERS *****			
18	160.50	256.00	7.474E+05	1.085E+05	7.258E+05
	160.50	274.00	7.474E+05	1.085E+05	1.226E+06
19	140.00	256.00	6.923E+05	6.392E+05	8.130E+06
	140.00	274.00	6.923E+05	6.392E+05	3.376E+06
20	150.00	278.50	8.731E+04	7.247E+05	6.341E+06
	158.00	277.58	8.731E+04	7.247E+05	5.047E+05
		***** STEM MEMBERS *****			
21	143.00	283.00	2.008E+04	3.697E+05	5.791E+06
	143.00	290.00	2.008E+04	3.697E+05	3.203E+06
22	143.00	290.00	1.367E+04	2.579E+05	3.182E+06
	143.00	298.00	1.367E+04	2.579E+05	1.118E+06

III.C.--CENTER STEM MEMBERS - TYPE C8 MONOLITH

III.C.1.--RIGHTSIDE CENTER STEM MEMBERS

MEM NO	DISTANCE FROM STRUC CL (FT)	ELEVATION (FT)	<--------FORCES (LB OR LB-FT)--------> AXIAL	SHEAR	MOMENT
1	22.00	256.00	8.795E+05	5.297E+05	4.980E+06
	22.00	274.00	8.795E+05	5.297E+05	4.555E+06
2	22.00	292.00	8.386E+04	2.673E+05	1.609E+06
	22.00	300.00	8.386E+04	2.673E+05	5.291E+05

III.C.2.-- LEFTSIDE CENTER STEM MEMBERS

MEM NO	DISTANCE FROM STRUC CL (FT)	ELEVATION (FT)	<--------FORCES (LB OR LB-FT)--------> AXIAL	SHEAR	MOMENT
1	22.00	256.00	8.795E+05	5.297E+05	4.980E+06
	22.00	274.00	8.795E+05	5.297E+05	4.555E+06
2	22.00	292.00	8.386E+04	2.673E+05	1.609E+06
	22.00	300.00	8.386E+04	2.673E+05	5.291E+05

III.C.3.--MEMBERS ON OR CROSSING STRUCTURE CENTERLINE

MEM NO	DISTANCE FROM STRUC CL (FT)	ELEVATION (FT)	<--------FORCES (LB OR LB-FT)--------> AXIAL	SHEAR	MOMENT
1	.00	256.00	2.541E-07	5.297E+05	4.980E+06
	.00	274.00	2.541E-07	5.297E+05	4.555E+06
3	-18.00	305.00	1.993E-07	7.580E+04	1.364E+06
	18.00	305.00	1.993E-07	7.580E+04	1.364E+06

Figure 28. (Sheet 5 of 6)

IV.--MAXIMUM PILE HEAD FORCES

IV.A.--RIGHTSIDE PILE HEAD FORCES

PILE NO.	DISTANCE FROM STRUC CL (FT)	<---------FORCES (LB OR LB-FT)---------> AXIAL	SHEAR	MOMENT
1	.00	6.021E-09	1.537E+05	7.870E+05
2	6.25	2.242E+04	1.537E+05	7.870E+05
3	12.50	4.485E+04	1.537E+05	7.870E+05
4	18.75	6.727E+04	1.537E+05	7.870E+05
5	25.00	8.969E+04	1.537E+05	7.870E+05
6	31.25	1.032E+05	1.550E+05	7.974E+05
7	37.50	1.045E+05	1.563E+05	8.072E+05
8	43.75	9.719E+04	1.573E+05	8.146E+05
9	50.00	8.373E+04	1.580E+05	8.202E+05
10	56.25	6.607E+04	1.586E+05	8.246E+05
11	68.75	3.080E+04	1.592E+05	8.293E+05
12	81.25	5.097E+04	1.590E+05	8.278E+05
13	93.75	8.887E+04	1.580E+05	8.199E+05
14	106.25	1.052E+05	1.559E+05	8.039E+05
15	112.50	9.875E+04	1.544E+05	7.927E+05
16	118.75	7.970E+04	1.526E+05	7.792E+05
17	125.00	4.561E+04	1.505E+05	7.630E+05
18	131.25	1.876E+04	1.479E+05	7.435E+05
19	137.50	9.100E+04	1.457E+05	7.267E+05
20	143.75	1.794E+05	1.457E+05	7.267E+05
21	150.00	2.748E+05	1.443E+05	7.159E+05
22	156.25	3.824E+05	1.433E+05	7.081E+05

IV.B.-- LEFTSIDE PILE HEAD FORCES

PILE NO.	DISTANCE FROM STRUC CL (FT)	<---------FORCES (LB OR LB-FT)---------> AXIAL	SHEAR	MOMENT
1	.00	6.021E-09	1.537E+05	7.870E+05
2	6.25	2.242E+04	1.537E+05	7.870E+05
3	12.50	4.485E+04	1.537E+05	7.870E+05
4	18.75	6.727E+04	1.537E+05	7.870E+05
5	25.00	8.969E+04	1.537E+05	7.870E+05
6	31.25	1.032E+05	1.550E+05	7.974E+05
7	37.50	1.045E+05	1.563E+05	8.072E+05
8	43.75	9.719E+04	1.573E+05	8.146E+05
9	50.00	8.373E+04	1.580E+05	8.202E+05
10	56.25	6.607E+04	1.586E+05	8.246E+05
11	68.75	3.080E+04	1.592E+05	8.293E+05
12	81.25	5.097E+04	1.590E+05	8.278E+05
13	93.75	8.887E+04	1.580E+05	8.199E+05
14	106.25	1.052E+05	1.559E+05	8.039E+05
15	112.50	9.875E+04	1.544E+05	7.927E+05
16	118.75	7.970E+04	1.526E+05	7.792E+05
17	125.00	4.561E+04	1.505E+05	7.630E+05
18	131.25	1.876E+04	1.479E+05	7.435E+05
19	137.50	9.100E+04	1.457E+05	7.267E+05
20	143.75	1.794E+05	1.457E+05	7.267E+05
21	150.00	2.748E+05	1.443E+05	7.159E+05
22	156.25	3.824E+05	1.433E+05	7.081E+05

Figure 28. (Sheet 6 of 6)

Appendix A
Guide for Data Input

Source of Input

Input data may be supplied from a predefined data file or from the user terminal during execution. If data are supplied from the user terminal, prompting messages are printed to indicate the amount and character of data to be entered.

Data Editing

When all data for a problem have been entered, the user is offered the opportunity to review an echoprint of the currently available input data and to revise any or all sections of the input data before execution is attempted. When data are edited during execution, each section must be entered in its entirety.

Input Data File Generation

After data have been entered from the terminal, initially or after editing, the user may direct the program to write the input data to a permanent file in input data file format.

Data Format

All input data (supplied from the user terminal or from a file) are read in free-field format:

a. Data items must be separated by one or more blanks (comma separators are not permitted).

b. Integer numbers must be of the form NNNN.

c. Real numbers may be of the form

±xxxx, ±xx.xx, or ±xx.xxE±ee

d. User responses to all requests for control by the program for alphanumeric input may be abbreviated by the first letter of the indicated word response, e.g.,

ENTER 'YES' OR 'NO' -- respond 'Y' OR 'N'

ENTER 'CONTINUE' OR 'END' -- respond 'C' or 'E'

Input data are divided into the following sections.

I. Heading (Required)
II. Structure Data
   A. Control (Required)
   B. Floor Data (Required)
   C. Base Data (Required)
   D. Stem Data (Required)
   E. Culvert Data (Optional)
   F. Void Data (Optional)
   G. Center Stem Data (Optional)
   H. Center Culvert(s) Data (Optional)
   I. Center Void Data (Optional)
III. Pile Data (Required)
IV. Acceleration Spectrum Data (Required)
V. Additional Weight Data (Optional)
VI. Termination (Required)

When data are entered from the terminal, prompts indicate the data items to be provided.

Units

The program expects data to be provided in units of inches, feet, pounds, or kips as noted in the following guide. No provision is made for conversion of any other system of units by the program.

Predefined Data File

In addition to the general format requirements given in the paragraph on "Data Format," page A1 of this appendix, the following pertain to a predefined data file and to the input data description beginning in paragraph on "STRUCTURE," page A4.

a. Each line must commence with a nonzero, positive line number denoted LN in the following paragraphs.

b. A line of input may require both alphanumeric and numeric data items. Alphanumeric data items are enclosed in single quotes in the following paragraphs.

c. A line of input may require a keyword. The acceptable abbreviation for the keyboard is indicated by underlined capital letters, e.g., the acceptable abbreviation for the keyword 'PROperties' is 'PRO'.

d. Lower case words in single quotes indicate definitions of a choice of keywords will follow.

e. Items designated by upper case letters and numbers without quotes indicate numeric data values. Numeric data values are real or integer, according to standard FORTRAN variable naming conventions.

f. Data items enclosed in brackets [] may not be required. Data items enclosed in braces { } indicate special note follows.

g. Comment lines may be inserted in the input file by enclosing the line, following the line number, in parentheses. Comment lines are ignored, e.g.,

1234 (THIS LINE IS IGNORED)

General Discussion of Input Data

Each data section contains a descriptor {'side'} to indicate the side of the structure to which the data apply. For symmetric effects ({'side'} = Both'), the data section is entered only once and symmetric data are applied to both sides automatically. For unsymmetric conditions, except for pile data, the description for the rightside[1] (if present) must be entered first and must be immediately followed by the description for the leftside[1] (if present). In the case of pile data, all pile data subsections must be entered for the rightside first, followed by all pile data subsections for the leftside.

Rightside and leftside descriptions must be supplied explicitly or implicitly (i.e., {'side'} = 'Both') for the required data sections indicated in the paragraph listing sections of input data on page A2. Optional data sections may be supplied for the rightside, leftside, both sides, or may be omitted.

[1] The terms "rightside," "leftside," and "centerline" are each used in a one-word form in the appendixes to be consistent with these terms as used in the computer program output.

Input Description

HEADING--One (1) to four (4) lines

a. Line contents

LN {'heading'}

b. Definition

'heading' = any alphanumeric information up to 70 characters including LN and any embedded blanks. The first nonblank character following LN must be a single quote (').

STRUCTURE

a. Control--One (1) line

(1) Line contents

LN 'Structure' EC PR WTCONC SLICE RLF

(2) Definitions

'Structure' = keyword

EC = modulus of elasticity of concrete (PSI)

PR = Poisson's ratio for concrete ($0 < PR < 0.5$)

WTCONC = unit weight of concrete (PCF)

SLICE = thickness of slice of structure to be considered (FT); assumed to be one (1) ft if omitted

RLF = rigid block reduction factor ($O \leq RLF \leq 1$)

(3) Discussion

Any width of slice of structure to be analyzed may be used. A slice width other than 1 ft may facilitate describing other effects (e.g., pile foundation) on the structure.

b. Floor data--One (1) line

(1) Line contents

LN 'Floor' FLRWID ELFLOR

(2) Definitions

'Floor' = keyword

FLRWID = distance from centerline to inside face of outside stem (FT)

ELFLOR = elevation of chamber floor (FT)

(3) Discussion

(a) See Figure A1 for notation.

(b) All 'Floor' and 'Base' distances are measured from the centerline; i.e., from midpoint between interior stem faces of the outside stems.

c. Base data--One (1) or two (2) lines

(1) Line contents

LN 'Base' {'side'} DBASE(1) ELBASE(1)
[DBASE(2) ELBASE(2)]

(2) Definitions

'Base' = keyword

{'side'} = 'Rightside', 'Leftside', or 'Both'

DBASE(1) = distance from chamber centerline to first base point (FT)

ELBASE(1) = elevation at base point (FT)

DBASE(2) = distance from centerline to second base point (FT)

ELBASE(2) = elevation at second base point (FT)

(3) Discussion

(a) See Figure A2 for notation.

(b) Base points, define locations where changes in slope of the base occur. Up to two (2) points may be defined on either side of the centerline. The base is assumed to be horizontal

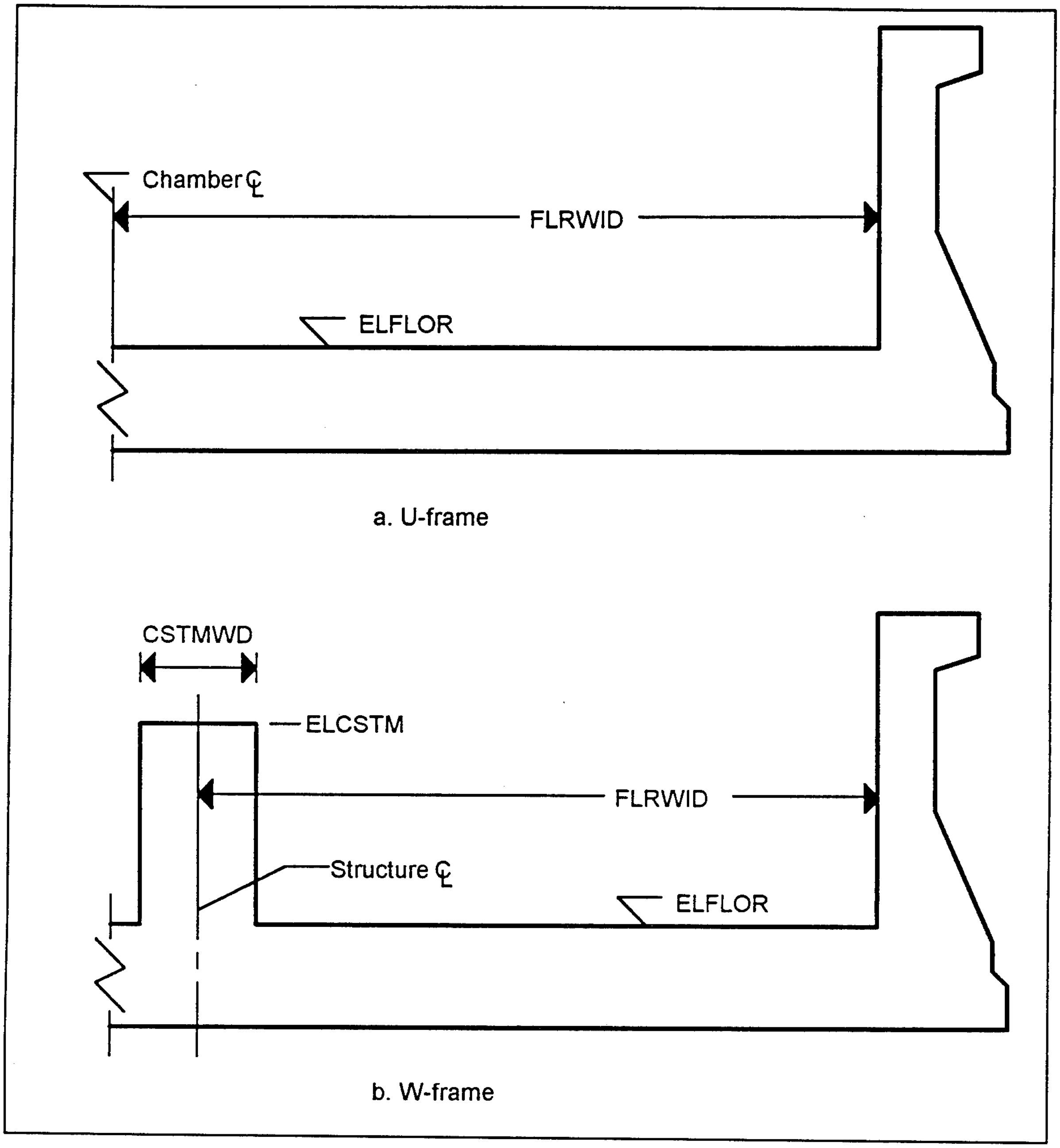


Figure A1. U-FRAME and W-FRAME structures

from the centerline to the first point as is assumed to be straight between input points.

(c) If only one base point is provided, DBASE(1) must be greater than zero.

(d) If two points are provided, the following must be satisfied:

$DBASE(1) \geq 0$

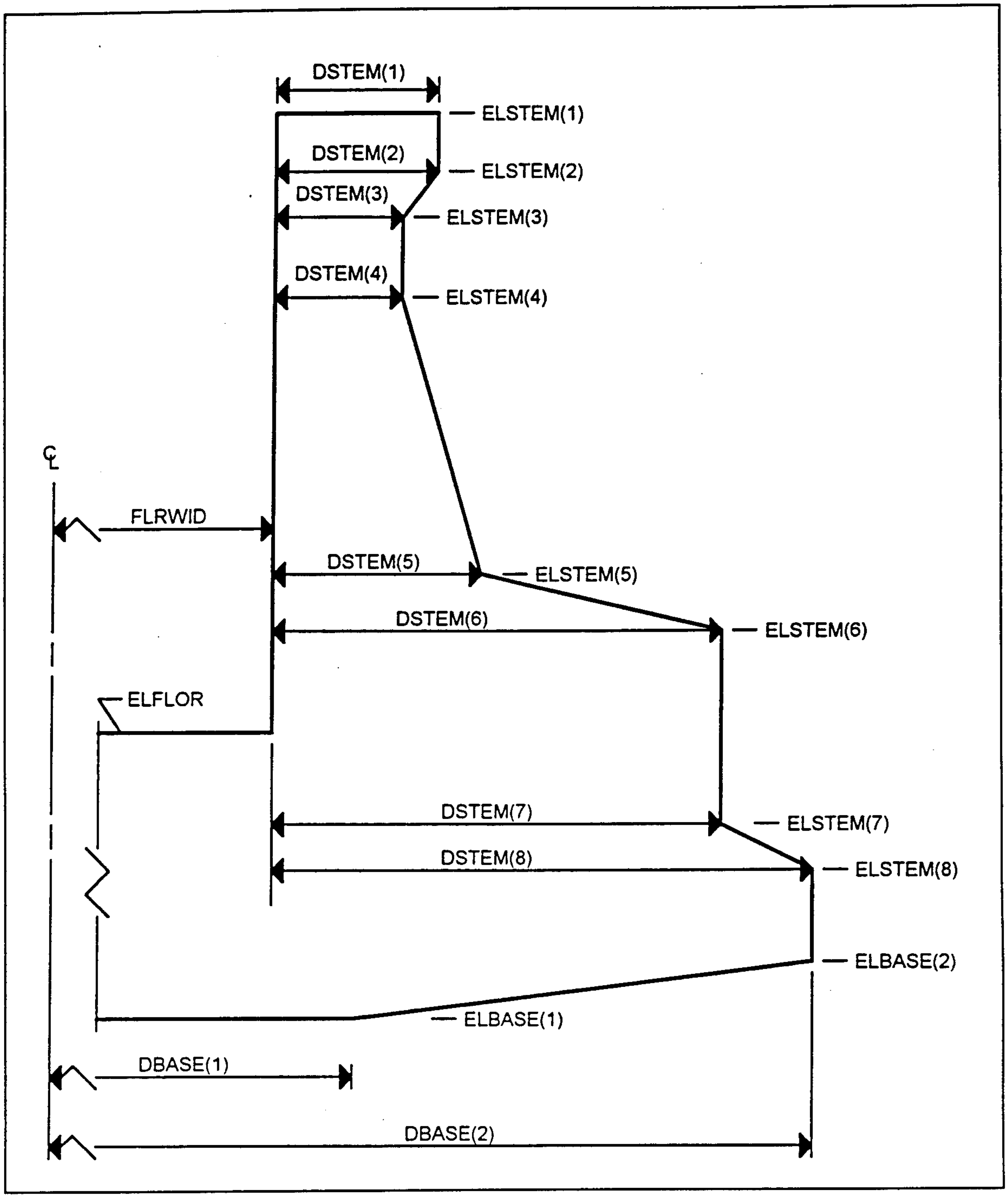


Figure A2. Base and outside stem

DBASE(2) > DBASE(1)

(e) Distances and elevations for some data items in subsequent sections are restricted by the base dimensions. For reference the limits are expressed in terms of DBASE(2) and

ELBASE(2). If only one base point has been provided, DBASE(2) = DBASE(1) and ELBASE(2) = ELBASE(1).

(f) If {'side'} = 'Both', identical base point data are assigned to both sides of the structure base.

(g) If 'Rightside' and 'Leftside' base data differ, 'Rightside' ELBASE(1) must be equal to 'Leftside' ELBASE(1). Enter 'Rightside' base data first and immediately follow with 'Leftside' data.

d. External stem data--One (1) or more lines

(1) Line contents

LN 'Stem' {'side'} NPTS DSTEM(1) ELSTEM(1)...

[LN...DSTEM(NPTS) ELSTEM(NPTS)]

(Continue DSTEM, ELSTEM pairs on additional lines following line number until NPTS pairs provided)

(2) Definitions

'Stem' = keyword

{'side'} = 'Rightside', 'Leftside', or 'Both'

NPTS = number (1 to 8) of stem points

DSTEM(i) = distance from inside face of stem to i^{th} stem point (FT)

ELSTEM(i) = elevation at i^{th} stem point (FT)

(3) Discussion

(a) See Figure A2 for notation.

(b) If {'side'} = 'Both', identical stems are assumed.

(c) DSTEM, ELSTEM pairs must start at the top of the stem and proceed sequentially downward with:

DSTEM(1) > 0

ELSTEM(1) ≤ ELSTEM(I - 1)

ELSTEM(NPTS) > ELBASE(2)

(d) The top of the stem is assumed to be horizontal at ELSTEM(1).

(e) Successive stem points are assumed to be connected by straight lines.

(f) The last stem point provided is connected by a straight line to the last base point provided.

(g) The number of stem points and locations of stem points must conform to limitations described for {'mode'} = 'Frame' in Part V of Instruction Report ITL-90-6 by Jordan and Dawkins.[1]

(h) If 'Rightside' and 'Leftside' stem geometries differ, enter 'Rightside' base data first and immediately follow with 'Leftside' data.

e. Culvert data--Zero (0) or one (1) line, entire section may be omitted

(1) Line contents

[LN 'Culvert' {'side'} DCUL CULWID ELCUL CULHGT]

(2) Definitions

'Culvert' = keyword

{'side'} = 'Rightside', 'Leftside', or 'Both'

DCUL = distance from inside stem face to interior vertical side of culvert (FT)

CULWID = width of the culvert opening (FT)

ELCUL = elevation of the floor of culvert (FT)

CULHGT = height of culvert opening (FT)

(3) Discussion

(a) See Figure A3 for notation.

(b) If {'side'} = 'Both', identical culverts are assigned to both sides of the structure.

---

[1] T. D. Jordan and W. P. Dawkins. (1990). "User's guide: Computer programs for two-dimensional analysis of U-Frame or W-Frame structures (CDWFRAM)," Instruction Report ITL-90-6, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

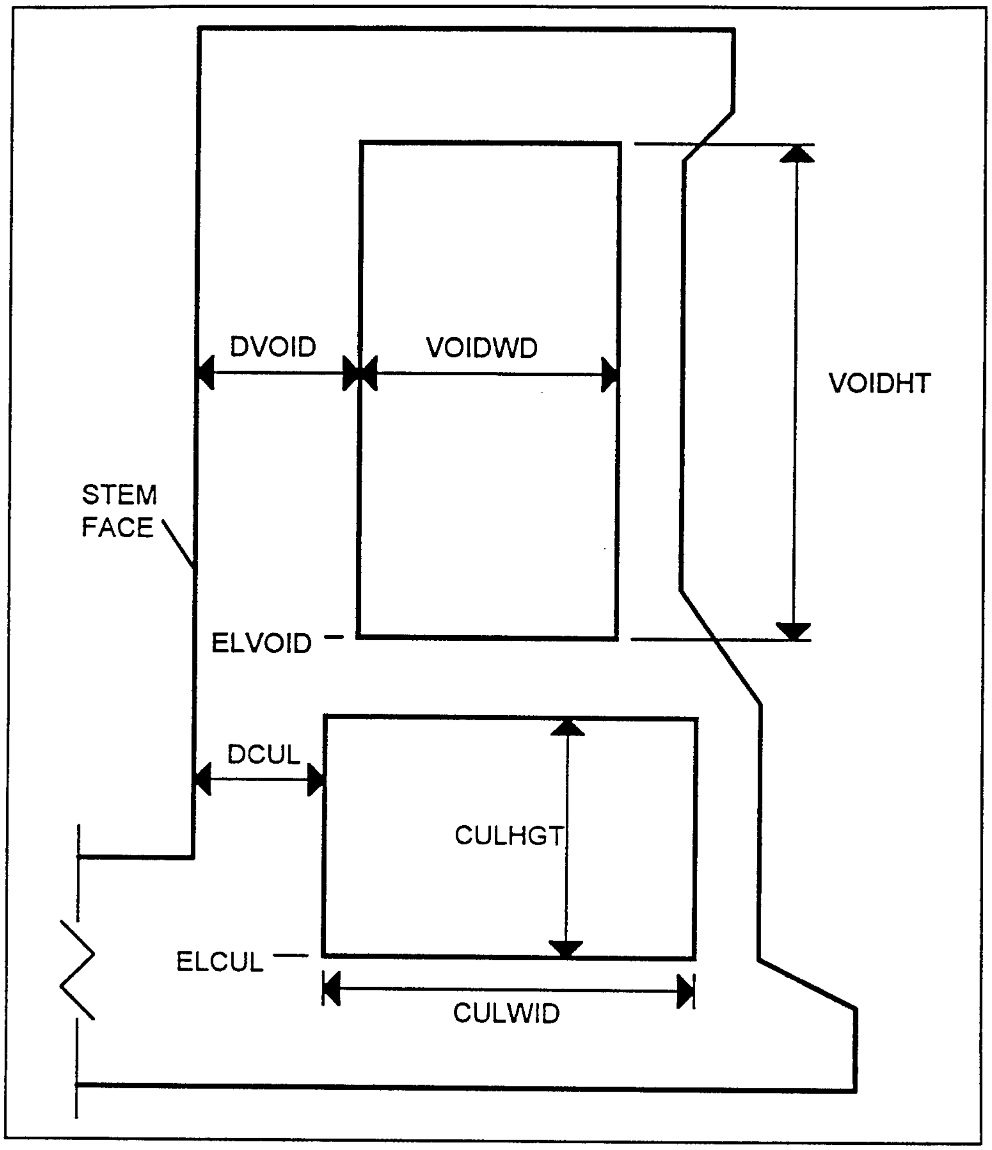


Figure A3. Outside stem culvert and void

(c) If culvert data are provided for one side only, no culvert is assumed for the opposite side.

(d) A rectangular culvert is assumed. Culvert dimensions must result in the culvert opening lying entirely within the external boundaries defined by the stem and base data.

(e) If different culverts occur on each side, enter 'Rightside' data first and immediately follow with 'Leftside' data.

(f) Culvert locations must conform to limitations described by Jordan and Dawkins.[1]

f. Stem void data--Zero (0) or one (1) line, entire section may be omitted.

(1) Line 1 contents

[LN 'Void' {'side'} DVOID VOIDWD ELVOID VOIDHT]

(2) Definitions

'Void' = keyword

{'side'} = 'Rightside', 'Leftside', or 'Both'

DVOID = distance from inside stem face to interior vertical side of void (FT)

VOIDWD = width of void opening (FT)

ELVOID = elevation of bottom of void opening (FT)

VOIDHT = height of void opening (FT)

(3) Discussion

(a) See Figure A3 for notation.

(b) If {'side'} = 'Both', identical voids are assumed to exist in stems on both sides.

(c) If void data are provided for one side only, no void is assumed in the opposite stem.

(d) The void is assumed to be a rectangular opening and must lie entirely within the external boundaries defined by the stem and base date.

(e) Void data must satisfy the following:

$$ELVOID \geq (ELCUL + CULHGT) \text{ if culvert present}$$

$$(ELVOID + VOIDHT) \leq ELSTEM(1)$$

(f) If ELVOID = (ELCUL + CULHGT), the top of the culvert is assumed to be open to the void.

---

[1] Op. cit., p A9.

(g) If (ELVOID + VOIDHT) < ELSTEM(1), the void is treated as a separate rectangular opening in the stem.

g. Center Stem--Zero (0) or one (1) line

(1) Line contents

[LN 'Stem Center' CSTMWD ELCSTM]

(2) Definitions

'Stem Center' = keyword

CSTMWD = width of center stem (FT)

ELCSTM = elevation of center stem (FT)

(3) Discussion

(a) See Figures A1 and A4 for notation.

(b) Center stem including culvert(s) and void is symmetric about the structure centerline.

(c) Base data must satisfy the following:

DBASE(1) > CSTMWD/2

(d) If a center stem is present, two chambers of equal width and floor elevation are defined.

(e) Floor data must satisfy the following:

FLRWID > CSTMWD/2

ELFLOR < ELCSTM

h. Center Culvert--Zero (0) or one (1) line

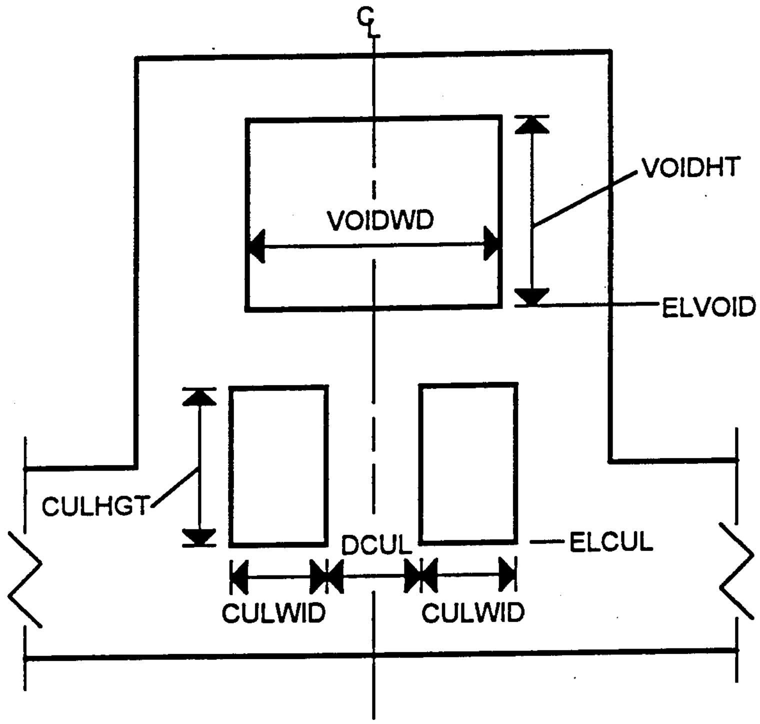
(1) Line contents

[LN 'Culvert Center' NCUL CULWID ELCUL CULHGT [DCUL]]

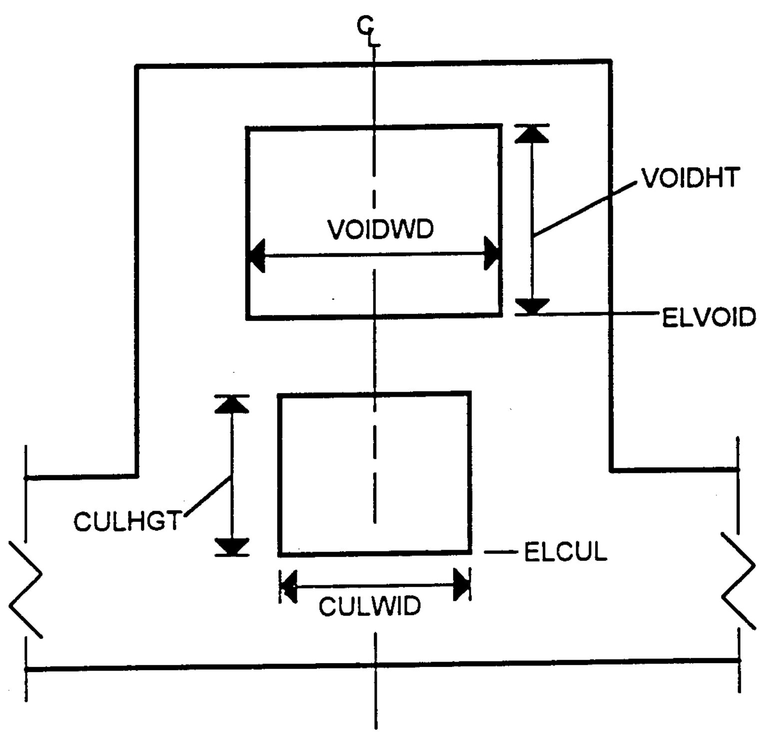
(2) Definitions

'Culvert Center' = keyword

NCUL = number of culverts



a. Two culverts



b. One culvert

Figure A4. Center stem culvert(s) and void

CULWID = width of culvert(s) opening (FT)

ELCUL = elevation of floor of culvert(s) (FT)

CULHGT = height of culvert(s) opening (FT)

[DCUL] = distance between culverts (FT), omit if NCUL = 1

(3) Discussion

(a) See Figure A4 for notation.

(b) Rectangular culverts are assumed. Culvert dimensions must result in the culvert openings lying entirely within the external boundaries defined by center stem and base data.

(c) Center culvert data must satisfy: ELCUL ≤ ELFLOR

i. Center Void--Zero (0) or one (1) line

(1) Line 1 contents

[LN 'Void Center' VOIDWD ELVOID VOIDHT]

(2) Definitions

'Void Center' = keyword

VOIDWD = width of void opening (FT)

ELVOID = elevation of bottom of void opening (FT)

VOIDHT = height of void opening (FT)

(3) Discussion

(a) See Figure A4 for notation.

(b) The void is assumed to be a rectangular opening and must lie entirely within the external boundaries defined by the center stem and base data.

(c) Void data must satisfy the following:

ELVOID ≥ (ELCUL + CULHGT) if culvert present

(ELVOID + VOIDHT) ≤ ELCSTM

(d) If (ELVOID + VOIDHT) < ELCSTM, the void is treated as a separate rectangular opening in the stem.

PILE DATA

a. Control--One (1) line

(1) Line contents

LN 'PILes {'side'}

(2) Definitions

'PILe' = keyword

{'side'} = 'Rightside', 'Leftside', or 'Both'

b. Pile layout--One (1) to ten (10) lines

(1) Line contents

LN 'Layout' NSTART DSTART [NSTOP [NSTEP [DSTEP]]]

(2) Definitions

'Layout' = keyword

NSTART = pile number at start of sequence

DSTART = distance (FT) from centerline to intersection of pile axis with base of structure

[NSTOP] = pile number of last pile in sequence

[NSTEP] = step in pile number

[DSTEP] = distance between adjacent pile in the sequence (FT)

(3) Discussion

(a) Piles on either side of the centerline are designated by an integer number from 1 to 50. A maximum of fifty (50) piles is permitted on each side of the structure. Pile numbers need not be entered in a sequential order. Any pile number in the range 1 to 50 for which layout data are not supplied is ignored.

(b) Each line of 'Layout' data describes one sequence of piles to be generated. Pile numbers and distances are generated for each sequence as follows:

Pile No.	Distance from Centerline
NSTART	DSTART
NSTART + NSTEP	DSTART + DSTEP
NSTART + (2 • NSTEP)	DSTART + (2 • DSTEP)
•	•
•	•
•	•
NSTOP	DSTART + [((NSTOP - NSTEP)/NSTEP} • DSTEP]

(c) (NSTOP - NSTART)/NSTEP must be an integer.

(d) If NSTOP, NSTEP, and DSTEP are all omitted, only one pile is generated.

(e) If NSTEP and DSTEP are omitted, NSTEP is assumed to be one and DSTEP is assumed to be zero. This results in piles NSTART, NSTART + 1, NSTART + 2, ..., NSTOP all attached to base of structure at DSTART.

(f) If DSTEP is omitted, DSTEP is assumed to be zero. This results in piles NSTART, NSTART + NSTEP, NSTART + (2 • NSTEP), ..., NSTOP all attached to base of structure at DSTART.

(g) Any pile generated beyond the extreme edge(s) of the base is ignored.

(h) If any pile is referenced more than once, only the data corresponding to the last reference are used.

(i) When {'side'} = 'Both', DSTART = 0 may result in two (or more) piles being placed at the centerline. See discussion of batter data below.

(j) Every pile referenced in the pile "Layout" data must be assigned either pile/soil data or a pile head stiffness matrix as described below.

c. Pile/soil properties--Zero (0) to ten (10) lines; entire section may be omitted.

(1) Line contents

LN 'PROperties' NSTART PE PA PI PL PAXCO DF SS1 SS2 [NSTOP [NSTEP]]

(2) Definitions

'PROperties' = keyword

NSTART = pile number at start of sequence

PE = pile modulus of elasticity (PSI)

PA = pile cross-sectional area (IN^2)

PI = pile moment of inertia (IN^4)

PL = pile length (FT)

PAXCO = coefficient for pile axial stiffness

DF = pile head fixity coefficient ($0 \leq DF \leq 1$); 0 = pinned head, 1 = fixed head

SS1 = constant soil stiffness coefficient (LB/IN^2)

SS2 = linear soil stiffness coefficient (LB/IN^3)

[NSTOP] = pile number of last pile in sequence

[NSTEP] = step in pile number

(3) Discussion

(a) Each line of data describes a sequence of piles to be generated.

(b) Identical pile properties, pile head fixity, and soil properties are assigned to all piles NSTART, NSTART + NSTEP, NSTART + (2 • NSTEP), ..., NSTOP.

(c) (NSTOP-NSTART)/NSTEP must be an integer.

(d) If NSTOP and NSTEP are both omitted, only a single pile is generated.

(e) If NSTEP is omitted, NSTEP is assumed to be one.

(f) If any pile is referenced more than once, only the data for the last reference are used.

(g) Soil stiffness is obtained from E_s = SS1 + (SS2 • Y) where E_s is the force per unit length of pile (LB/IN^2) produced by a unit lateral displacement, and Y is the distance below the pile head. Soil stiffness coefficients must include effects of pile width, as well as other factors which may influence the soil stiffness.

(h) Pile properties, pile head fixity, and soil properties are used to generate pile head stiffness matrices.

d. Pile head stiffness matrices--Zero (0) or one (1) to ten (10) lines; entire section may be omitted.

(1) Line contents

LN '<u>STIF</u>fness' NSTART B11 B22 B33 B13 [NSTOP [NSTEP]]

(2) Definitions

'<u>STIF</u>fness' = keyword

NSTART = pile number at start of sequence

B11 = pile lateral stiffness (LB/IN.)

B22 = pile axial stiffness (LB/IN.)

B33 = pile moment stiffness (LB/IN.)

B13 = lateral force-moment coupling stiffness (LB)

[NSTOP] = pile number of the last pile in sequence

[NSTEP] = step in pile number

(3) Discussion

(a) Each line of data describes a sequence of piles to be generated.

(b) Identical pile head stiffness matrices are assigned to all piles NSTART, NSTART + NSTEP, NSTART + 2 • NSTEP, ..., NSTOP.

(c) (NSTOP - NSTART)/NSTEP must be an integer.

(d) If NSTOP and NSTEP are both omitted, only a single pile is generated.

(e) If NSTEP is omitted, NSTEP is assumed to be one.

(f) If any pile is referenced more than once, only the data for the last reference are used.

e. Pile batter data--Zero (0) or one (1) to ten (10) lines; entire section may be omitted.

(1) Line contents

LN 'BATter' NSTART BATTER [NSTOP [NSTEP]]

(2) Definitions

'BATter' = keyword

NSTART = pile number of first pile in sequence

BATTER = slope of pile vertical (FT) per foot horizontal. Positive if pile slopes downward away from centerline; negative if pile slopes downward toward centerline

[NSTOP] = pile number of last pile in sequence

[NSTEP] = step in pile number

(3) Discussion

(a) Each line of data describes a sequence of piles to be generated.

(b) Identical pile batters are assigned to all piles NSTART, NSTART + NSTEP, NSTART + (2 • NSTEP), ..., NSTOP.

(c) (NSTOP - NSTART)/NSTEP must be an integer.

(d) If NSTOP and NSTEP are omitted, only a single pile is generated.

(e) If NSTEP is omitted, NSTEP is assumed to be zero.

(f) All piles are assumed to lie in a vertical plane. BATTER describes the slope of the pile within this vertical plane. When BATTER ≥ 100 or BATTER = 0, the pile is assumed to be exactly vertical. Any pile not assigned a batter is assumed to be exactly vertical.

(g) When all pile data are symmetric, vertical piles on the structure centerline are not duplicated in mirror image established for the 'Leftside'.

f. Pile head mass matrices--Zero (0) or one (1) to 10 lines; entire section may be omitted.

(1) Line contents

LN 'Masses' NSTART M11 M22 M33 M13 [NSTOP [NSTEP]]

(2) Definitions

'Masses' = keyword

NSTART = pile number of first pile in sequence

M11 = mass (SLUGS) associated with acceleration perpendicular to the axis of the pile

M22 = mass (SLUGS) associated with acceleration parallel to the axis of the pile

M33 = mass moment of inertia (SLUG-FT^2) associated with rotational accelerations of the pile head

M13 = mass (SLUG-FT) associated with coupling of lateral and rotational accelerations

(3) Discussion

(a) Each line of data describes a sequence of piles to be generated.

(b) Identical mass matrices are assigned to all piles NSTART, NSTART + NSTEP, NSTART + (2 * NSTEP), ..., NSTOP.

(c) (NSTOP - NSTART)/NSTEP must be an integer.

(d) If NSTOP and NSTEP are omitted, only a single pile is generated.

(e) If NSTEP is omitted, NSTEP is assumed to be one.

(f) If any pile is referenced more than once, only the data for the last reference are used.

g. General discussion of pile data.

(1) Pile layout data are used to determine the number of piles present and their identification. Every pile defined by the layout data must be assigned pile/soil data or pile head stiffness matrix; otherwise execution will terminate.

(2) Any pile number assigned pile/soil data or a pile head stiffness matrix but not defined by layout data is ignored.

(3) If different pile conditions exist on each side, enter the entire description for 'Rightside' piles ('Layout', 'PROperties', 'STIFFnesses', 'BATter', and 'Masses') first and immediately follow with 'Leftside' data.

ACCELERATION SPECTRUM DATA--Two (2) or more lines

a. Control--One (1) line

(1) Line contents

LN 'Acceleration' {'direction'} NPTS [DRATIO]

(2) Definitions

'Acceleration' = keyword

{'direction'} = 'Horizontal' or 'Vertical'

NPTS = number (2 to 100) of points on spectrum to be provided

[DRATIO] = constant damping ratio; assumed to be 0.05 if omitted

b. Data lines--One (1) or more lines

(1) Line contents

LN PERIOD(1) ACCEL(1)...

[LN...PERIOD(NPTS) ACCEL(NPTS)]

(2) Definitions

PERIOD(i) = period (SEC) at i^{th} spectrum point

ACCEL(i) = spectral acceleration (G's) at i^{th} spectrum point

(3) Discussion

(a) At least two points must be provided.

(b) Points must begin with the lowest PERIOD on the spectrum and conform to: PERIOD(i-1) < PERIOD(i).

(c) A straight line variation between adjacent points is assumed.

(d) The spectrum acceleration is assumed to be equal to ACCEL(1) for any period less than PERIOD(1).

(e) The spectrum acceleration is assumed to be equal to zero for any period greater than PERIOD(NPTS).

ADDITIONAL WEIGHT DATA--Zero (0), one (1), or two (2) or more lines. Entire section may be omitted or line sequences may be repeated as necessary.

a. Control--One (1) line.

(1) Outside Stem

(a) Line contents

LN 'Weight' {'side'} {'location'}

(b) Definitions

'Weight' = keyword

{'side'} = 'Rightside', 'Leftside', or 'Both'

{'location'} = 'Stem Exterior' if weight acts on exterior face of stem

= 'Stem Interior' if weight acts on interior face of stem

= 'Stem Top' if weight acts on top horizontal surface of stem

(2) Floor and Base

(a) Line contents

LN 'Weight' {'side'} {'location'}

(b) Definitions

'Weight' = keyword

{'side'} = 'Rightside', 'Leftside', or 'Both'

{'location'} = 'Floor' if weight acts on chamber floor

= 'Base' if weight acts on base of structure

(3) Center Stem

(a) Line contents

LN 'Weight' 'Center' {'location'} {'side'}

(b) Definitions

'Weight' 'Center' = keywords

{'location'} = 'Face' if weight acts on face of stem

= 'Top' if weight acts on top horizontal surface of stem

{'side'} = 'Rightside', 'Leftside', or 'Both'

b. Data lines for weights acting on stem faces.

(1) Concentrated weights--One (1) or more lines

(a) Line contents

LN 'Concentrated' NLDS ELCSLD(1) HCSLD(1) VCSLD(1)...

[LN...ELCSLD(NLDS) HCSLD(NLDS) VCSLD(NLDS)]

(b) Definitions

'Concentrated' = keyword

NLDS = number (1 to 10) of concentrated weights

ELCSLD = elevation at which weight acts (FT)

HCSLD = magnitude of weight (LB) associated with horizontal acceleration

VCSLD = magnitude of weight (LB) associated with vertical acceleration

(2) Distributed weights--One (1) or more lines

(a) Line contents

LN 'Distributed' NPTS ELDSLD(1) HDSLD(1) VDSLD(1)...

[LN...ELDSLD(NPTS) HDSLD(NPTS) VDSLD(NPTS)]

(b) Definitions

'Distributed' = keyword

NPTS = number (2 to 21) of weight point values to be provided

ELDSLD(I) = elevation at i^{th} weight point (FT)

HDSLD(I) = magnitude of weight (LB) associated with horizontal acceleration of i^{th} weight point (PSF)

VDSLD(I) = magnitude of weight associated with vertical acceleration at i^{th} weight point (PSF)

(3) Discussion

(a) All "horizontal" weights respond only to horizontal accelerations.

(b) All "vertical" weights respond only to vertical accelerations.

(c) For concentrated weights on interior face of outside stem:

$$ELBASE(2) \leq ELCSLD \leq ELSTEM(1)$$

(d) For concentrated weights on interior face of outside stem:

$$ELFLOR \leq ELCSLD \leq ELSTEM(1)$$

(e) For concentrated weights on face of center stem:

$$ELFLOR \leq ELCSLD \leq ELCSTM$$

(f) Concentrated weights are interpreted as line weights acting on the slice.

(g) Three values are required for each point on a distributed weight distribution. Continue groups of three on additional lines commencing with a line number until NPTS groups have been provided.

(h) Distributed weights on the exterior face of outside stem must begin at or below the top of the stem and terminate at or above the juncture of the base and stem, i.e.,

$$\text{ELDSLD}(1) \leq \text{ELSTEM}(1)$$

$$\text{ELDSLD}(I) \leq \text{ELDSLD}(I - 1)$$

$$\text{ELDSLD}(\text{NPTS}) \geq \text{ELBASE}(2)$$

(i) Distributed weights on the interior face of outside stem must begin at or below the top of the stem and terminate at or above the chamber floor, i.e.,

$$\text{ELDSLD}(1) \leq \text{ELSTEM}(1)$$

$$\text{ELDSLD}(I) \leq \text{ELDSLD}(I - 1)$$

$$\text{ELDSLD}(\text{NPTS}) \geq \text{ELFLOR}$$

(j) Distributed weights on the face of the center stem must begin at or below the top of the stem and terminate at or below the chamber floor, i.e.,

$$\text{ELDSLD}(1) \leq \text{ELCSTM}$$

$$\text{ELDSLD}(I) \leq \text{ELDSLD}(I - 1)$$

$$\text{ELDSLD}(\text{NPTS}) \geq \text{ELFLOR}$$

(k) Distributed weights are assumed to vary linearly between input points.

(l) If two weight points are specified at the same elevation, the first point is assumed to exits immediately above the elevation and the second immediately below the elevation.

(m) Distributed weights are interpreted as weight per foot of slice per foot of vertical projection of the stem surface.

c. Data lines for weights acting on top horizontal surface of stem.

(1) Concentrated weights--One (1) or more lines

(a) Line contents

LN 'Concentrated' NLDS DCSTLD(1) HCSTLD(1) VCSTLD(1)...

[LN...DCSTLD(NLDS) HCSTLD(NLDS) VCSTDL(NLDS)]

(b) Definitions

'Concentrated' = keyword

NLDS = number (1 to 10) of concentrated weights

DCSTLD = distance from inside stem face at which weight acts (FT)

HCSTLD = magnitude of "horizontal" weight component PLF)

VCSTLD = magnitude of "vertical" weight component (PLF)

(2) Distributed weights--One (1) or more lines

(a) Line contents

LN 'Distributed' NPTS DDSTLD(1) HDSTLD(1) VDSTLD(1)...

[LN...DDSTLD(NPTS) HDSTLD(NPTS) VDSTLD(NPTS)]

(b) Definitions

'Distributed' = keyword

NPTS = number (2 to 21) of weight point values to be provided

DDSTLD(I) = distance from inside stem face to i^{th} weight point (FT)

HDSTLD(I) = magnitude of the "horizontal" weight at i^{th} weight point (PSF)

VDSTLD(I) = magnitude of the "vertical" weight at i^{th} weight point (PSF)

(3) Discussion

(a) All "horizontal" weights respond only to horizontal accelerations

(b) All "vertical" weights respond only to vertical accelerations

(c) If the top of a stem void is open at the top of the stem, weights may not be applied inside of the void opening.

(d) For concentrated weights on top of outside stem:

$$0.0 \leq DCSTLD(I) \leq DSTEM(1)$$

(e) For concentrated weights on top of center stem:

$$0.0 \leq DCSTLD(I) \leq CSTMWD/2$$

(f) Concentrated weights are interpreted as line weights acting on the slice.

(g) Three values are required for each point on a distributed weight distribution. Continue groups of three on additional lines commencing with a line number until NPTS groups have been provided.

(h) For distributed weights on top of outside stem:

$$0.0 \leq DDSTLD(I) \leq DSTEM(1)$$

$$DDSTLD(I) \geq DDSTLD(I - 1)$$

(i) For distributed weights on top of center stem:

$$0.0 \leq DDSTLD(I) \leq CSTMWD/2$$

$$DDSTLD(I) \geq DDSTLD(I - 1)$$

(j) Distributed weights are assumed to vary linearly between input points.

(k) If two points are input at the same distance from the stem face, the first is assumed to exist immediately inside the point and the second is assumed to exist immediately outside the point.

(l) Distributed weights are interpreted as weight per foot of slice per foot of horizontal stem top surface.

d. Data lines for weights acting on chamber floor and structure base.

(1) Concentrated weights--One (1) or more lines

(a) Line contents

LN "Concentrated' NLDS DCFBLD(1) HCFBLD(1) VCFBLD(1)...

[LN...DCFBLD(NLDS) HCFBLD(NLDS) VCFBLD(NLDS)]

(b) Definitions

'Concentrated' = keyword

NLDS = number (1 to 10) of concentrated weights

DCFBLD = distance from centerline at which weight acts

HCFBLD = magnitude of "horizontal" weight component (PLF)

VCFBLD = magnitude of "vertical" weight component (PLF)

(2) Distributed weights--One (1) or more lines

(a) Line contents

LN 'Distributed' NPTS DDFBLD(1) HDFBLD(1) VDFBLD(1)...

[LN...DDFBLD(NPTS) HDFBLD(NPTS) VDFBLD(NPTS)]

(b) Definitions

'Distributed' = keyword

NPTS = number (2 to 21) of weight point values to be provided

DDFBLD(I) = distance from centerline to i^{th} weight point (FT)

HDFBLD(I) = magnitude of "horizontal" weight at i^{th} weight point (PSF)

VDFBLD(I) = magnitude of "vertical" weight at i^{th} weight point (PSF)

(3) Discussion

(a) All "horizontal" weights respond only to horizontal accelerations.

(b) All "vertical" weights respond only to vertical acceleration.

(c) For concentrated weights on the chamber floor of a U-FRAME structure:

$$0.0 \leq DCFBLD(I) \leq FLRWID$$

(d) For concentrated weights on a chamber floor of a W-FRAME structure:

$$CSTMWD/2 \leq DCFBLD(I) \leq FLRWID$$

(e) For concentrated weights on the structure base.

$$0.0 \leq DCFBLD(I) \leq DBASE(2)$$

(f) Concentrated weights are interpreted as lines of weight acting on slice.

(g) Three values are required for each point on a distributed weight distribution. Continue groups of three on additional lines commencing with a line number until NPTS groups have been provided.

(h) For distributed weights on the chamber floor of a U-FRAME structure:

$$0.0 \leq DDFBLD(1)$$

$$DDFBLD(I) \geq DDFBLD(I - 1)$$

$$DDFBLD(NPTS) \leq FLRWID$$

(i) For distributed weights on a chamber floor of a W-FRAME structure:

$$CSTMWD/2 \leq DDFBLD(1)$$

$$DDFBLD(I) \geq DDFBLD(I - 1)$$

$$DDFBLD(NPTS) \leq FLRWID$$

(j) For distributed weights on structure base:

$$0.0 \leq DDFBLD(1)$$

$$DDFBLD(I) \geq DDFBLD(I - 1)$$

$$DDFBLD(NPTS) \leq DBASE(2)$$

(k) If two points are input at the same distance from the stem face, the first is assumed to exist immediately inside the point and the second is assumed to exist immediately outside the point.

(l) Distributed weights are interpreted as weight per foot of slice per foot of horizontal projection of the base.

TERMINATION--One (1) line

LN 'Finish'

Appendix B
Abbreviated Input Guide

HEADING--One (1) to four (4) lines

LN 'heading'

STRUCTURE

a. Control--One (1) line

LN 'Structure' EC PR WTCONC SLICE RLF

b. Floor--One (1) line

LN 'Floor' FLRWID ELFLOR

c. Base--One (1) line

LN 'Base' {'side'} DBASE(1) ELBASE(1) [DBASE(2) ELBASE(2)]

d. Stem--One (1) or more lines

LN 'Stem' {'side'} NPTS DSTEM(1) ELSTEM(1) ... DSTEM(NPTS) ELSTEM(NPTS)

e. External Culvert--Zero (0) or one (1) line

[LN 'Culvert' {'side'} DCUL CULWID ELCUL CULHGT]

f. External Void--Zero (0) or one (1) line

[LN 'Void' {'side'} DVOID VOIDWD ELVOID VOIDHT]

g. Center Stem--Zero (0) or one (1) line

[LN 'Stem Center' CSTMWD ELCSTM]

h. Center Culvert--Zero (0) or one (1) line

[LN 'Culvert Center' NCUL CULWID ELCUL CULHGT [DCUL]]

i. Center Void--Zero (0) or one (1) line

[LN 'Void Center' VOIDWD ELVOID VOIDHT]

PILES

a. Control--One (1) line

LN 'Pile' {'side'}

b. Pile layout--One (1) to ten (10) lines

LN 'Layout' NSTART DSTART [NSTOP [NSTEP [DSTEP]]]

c. Pile properties--Zero (0) or one (1) to ten (10) lines; required if pile head stiffness matrices are calculated by program

LN 'PROperties' NSTART PE PD PA PI PL PAXCO DF SS1 SS2 [NSTOP [NSTEP]]

d. Pile stiffness matrices--Zero (0) or one (1) to ten (10) lines

LN 'STIFfness' NSTART B11 B22 B33 B13 [NSTOP [NSTEP]]

e. Pile batter--Zero (0) or one (1) to ten (10) lines

LN 'BATter' NSTART BATTER [NSTOP [NSTEP]]

f. Pile head mass matrices--Zero (0) or one (1) to ten (10) lines

LN 'Mass' NSTART M11 M22 M33 M13 [NSTEP [NSTOP]]

ACCELERATION RESPONSE SPECTRUM

a. Control--One (1) line

LN 'Acceleration {'Horizontal' / 'Vertical'} NPTS [DRATIO]

b. Spectrum values--One (1) or more lines

LN PERIOD(1) ACCEL(1) ... PERIOD(NPTS) ACCEL(NPTS)

ADDITIONAL WEIGHTS

a. Weights on stem faces--Zero (0) or two (2) or more lines

(1) Control--One (1) line

(a) Outside Stem--One (1) line

LN 'Weights' {'side'} {'Stem Exterior'}

OR

LN 'Weights' {'side'} {'Stem Internal'}

OR

(b) Center Stem--One (1) line

LN {'Weights Center Face'} {'side'}

(2) Data lines for concentrated weights--Zero (0) or one (1) or more lines

LN 'Concentrated' NLDS ELCSLD(1) HCSLD(1) VCSLD(1) ...

[LN ... ELCSLD(NLDS) HCSLD(NLDS) VCSLD(NLDS)]

(3) Data lines for distributed weights--Zero (0) or one (1) or more lines

LN 'Distributed' NPTS ELDSLD(1) HDSLD(1) VDSLD(1) ...

[LN ... ELDSLD(NPTS) HDSLD(NPTS) VDSLD(NPTS)]

b. Weights on stem top--Zero (0) or two (2) or more lines

(1) Control--One (1) line

(a) Outside Stem--One (1) line

LN 'Weights' {'side'} {'Stem Top'}

OR

(b) Center Stem--One (1) line

LN {'Weights Center Top' } {'side'}

(2) Data lines for concentrated weights--Zero (0) or one (1) or more lines

LN 'Concentrated' NLDS DCSTLD(1) HCSTLD(1) VCSTLD(1) ...

[LN ... DCSTLD(NLDS) HCSTLD(NLDS) VCSTLD(NLDS)]

(3) Data lines for distributed weights--Zero (0) or one (1) or more lines

LN 'Distributed' NPTS DDSTLD(1) HDSTLD(1) VDSTLD(1) ...

[LN ... DDSTLD(NPTS) HDSTLD(NPTS) VDSTLD(NPTS)]

c. Weights on chamber floor or structure base--Zero (0) or two (2) or more lines

(1) Control--One (1) line

LN 'Loads' {'side'} {'Floor'}

OR

LN 'Loads' {'side'} {'Base'}

(2) Data lines for concentrated weights--Zero (0) or one (1) or more lines

LN 'Concentrated' NLDS DCFBLD(1) HCFBLD(1) VCFBLD(1) ...

[LN ... DCFBLD(NLDS) HCFBLD(NLDS) VCFBLD(NLDS)]

(3) Data lines for distributed loads--Zero (0) or one (1) or more lines

LN 'Distributed' NPTS DDFBLD(1) HDFBLD(1) VDFBLD(1)

[LN ... DDFBLD(NPTS) HDFBLD(NPTS) VDFBLD(NPTS)]

TERMINATION--One (1) line

LN 'Finish'

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
June 1996

3. REPORT TYPE AND DATES COVERED
Final report

4. TITLE AND SUBTITLE
User's Guide: Computer Program for Two-Dimensional Dynamic Analysis of U-Frame or W-Frame Structures (CDWFRM)

5. FUNDING NUMBERS
IPA No 93-15-M

6. AUTHOR(S)
William P. Dawkins

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION REPORT NUMBER
Instruction Report ITL-96-1

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Corps of Engineers
Washington, DC 20314-1000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
This user's manual is available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. The computer program is available to U.S. Government employees only and can be obtained through the Engineering Computer Program Library at the U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This user's guide describes a computer program "CDWFRM" for dynamic analysis of a two-dimensional (2-D) slice of a U-frame of W-frame structure. "CDWFRM" is a companion to the program "CDFRAM" for static analysis of these structures and relies heavily on the documentation for that program. The program functions in the frame analysis mode, in which a 2-D plane frame model of a pile supported monolithic concrete structure is formulated. The effects of soil and/or water in the model of the system must be explicitly provided by the user with the "additional weight" facility described subsequently. Displacements and internal forces throughout the structure, including pile forces, induced by an earthquake excitation are determined from a linearly elastic model analysis. This program provides information regarding the response of the structure only, performs no design functions, nor does it attempt to judge the quality of the structural performance.

14. SUBJECT TERMS
CDWFRM (Computer Program)
Structural frames
Structural analysis

15. NUMBER OF PAGES
110

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

	Title	Date
Technical Report K-78-1	List of Computer Programs for Computer-Aided Structural Engineering	Feb 1978
Instruction Report O-79-2	User's Guide: Computer Program with Interactive Graphics for Analysis of Plane Frame Structures (CFRAME)	Mar 1979
Technical Report K-80-1	Survey of Bridge-Oriented Design Software	Jan 1980
Technical Report K-80-2	Evaluation of Computer Programs for the Design/Analysis of Highway and Railway Bridges	Jan 1980
Instruction Report K-80-1	User's Guide: Computer Program for Design/Review of Curvilinear Conduits/Culverts (CURCON)	Feb 1980
Instruction Report K-80-3	A Three-Dimensional Finite Element Data Edit Program	Mar 1980
Instruction Report K-80-4	A Three-Dimensional Stability Analysis/Design Program (3DSAD)	
	Report 1: General Geometry Module	Jun 1980
	Report 3: General Analysis Module (CGAM)	Jun 1982
	Report 4: Special-Purpose Modules for Dams (CDAMS)	Aug 1983
Instruction Report K-80-6	Basic User's Guide: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Dec 1980
Instruction Report K-80-7	User's Reference Manual: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Dec 1980
Technical Report K-80-4	Documentation of Finite Element Analyses	
	Report 1: Longview Outlet Works Conduit	Dec 1980
	Report 2: Anchored Wall Monolith, Bay Springs Lock	Dec 1980
Technical Report K-80-5	Basic Pile Group Behavior	Dec 1980
Instruction Report K-81-2	User's Guide: Computer Program for Design and Analysis of Sheet Pile Walls by Classical Methods (CSHTWAL)	
	Report 1: Computational Processes	Feb 1981
	Report 2: Interactive Graphics Options	Mar 1981
Instruction Report K-81-3	Validation Report: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Feb 1981
Instruction Report K-81-4	User's Guide: Computer Program for Design and Analysis of Cast-in-Place Tunnel Linings (NEWTUN)	Mar 1981
Instruction Report K-81-6	User's Guide: Computer Program for Optimum Nonlinear Dynamic Design of Reinforced Concrete Slabs Under Blast Loading (CBARCS)	Mar 1981
Instruction Report K-81-7	User's Guide:Computer Program for Design or Investigation of Orthogonal Culverts (CORTCUL)	Mar 1981
Instruction Report K-81-9	User's Guide:Computer Program for Three-Dimensional Analysis of Building Systems (CTABS80)	Aug 1981
Technical Report K-81-2	Theoretical Basis for CTABS80:A Computer Program for Three-Dimensional Analysis of Building Systems	Sep 1981
Instruction Report K-82-6	User's Guide:Computer Program for Analysis of Beam-Column Structures with Nonlinear Supports (CBEAMC)	Jun 1982

(Continued)

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

(Continued)

	Title	Date
Instruction Report K-82-7	User's Guide: Computer Program for Bearing Capacity Analysis of Shallow Foundations (CBEAR)	Jun 1982
Instruction Report K-83-1	User's Guide:Computer Program with Interactive Graphics for Analysis of Plane Frame Structures (CFRAME)	Jan 1983
Instruction Report K-83-2	User's Guide:Computer Program for Generation of Engineering Geometry (SKETCH)	Jun 1983
Instruction Report K-83-5	User's Guide:Computer Program to Calculate Shear, Moment, and Thrust (CSMT) from Stress Results of a Two-Dimensional Finite Element Analysis	Jul 1983
Technical Report K-83-1	Basic Pile Group Behavior	Sep 1983
Technical Report K-83-3	Reference Manual: Computer Graphics Program for Generation of Engineering Geometry (SKETCH)	Sep 1983
Technical Report K-83-4	Case Study of Six Major General-Purpose Finite Element Programs	Oct 1983
Instruction Report K-84-2	User's Guide: Computer Program for Optimum Dynamic Design of Nonlinear Metal Plates Under Blast Loading (CSDOOR)	Jan 1984
Instruction Report K-84-7	User's Guide: Computer Program for Determining Induced Stresses and Consolidation Settlements (CSETT)	Aug 1984
Instruction Report K-84-8	Seepage Analysis of Confined Flow Problems by the Method of Fragments (CFRAG)	Sep 1984
Instruction Report K-84-11	User's Guide for Computer Program CGFAG, Concrete General Flexure Analysis with Graphics	Sep 1984
Technical Report K-84-3	Computer-Aided Drafting and Design for Corps Structural Engineers	Oct 1984
Technical Report ATC-86-5	Decision Logic Table Formulation of ACI 318-77, Building Code Requirements for Reinforced Concrete for Automated Constraint Processing, Volumes I and II	Jun 1986
Technical Report ITL-87-2	A Case Committee Study of Finite Element Analysis of Concrete Flat Slabs	Jan 1987
Instruction Report ITL-87-1	User's Guide: Computer Program for Two-Dimensional Analysis of U-Frame Structures (CUFRAM)	Apr 1987
Instruction Report ITL-87-2	User's Guide: For Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-83	May 1987
Technical Report ITL-87-6	Finite-Element Method Package for Solving Steady-State Seepage Problems	May 1987
Instruction Report ITL-87-3	User's Guide: A Three Dimensional Stability Analysis/Design Program (3DSAD) Module	Jun 1987
	Report 1: Revision 1: General Geometry	Jun 1987
	Report 2: General Loads Module	Sep 1989
	Report 6: Free-Body Module	Sep 1989

(Continued)

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

(Continued)

	Title	Date
Instruction Report ITL-87-4	User's Guide: 2-D Frame Analysis Link Program (LINK2D)	Jun 1987
Technical Report ITL-87-4	Finite Element Studies of a Horizontally Framed Miter Gate Report 1: Initial and Refined Finite Element Models (Phases A, B, and C), Volumes I and II Report 2: Simplified Frame Model (Phase D) Report 3: Alternate Configuration Miter Gate Finite Element Studies–Open Section Report 4: Alternate Configuration Miter Gate Finite Element Studies–Closed Sections Report 5: Alternate Configuration Miter Gate Finite Element Studies–Additional Closed Sections Report 6: Elastic Buckling of Girders in Horizontally Framed Miter Gates Report 7: Application and Summary	Aug 1987
Instruction Report GL-87-1	User's Guide: UTEXAS2 Slope-Stability Package; Volume I, User's Manual	Aug 1987
Instruction Report ITL-87-5	Sliding Stability of Concrete Structures (CSLIDE)	Oct 1987
Instruction Report ITL-87-6	Criteria Specifications for and Validation of a Computer Program for the Design or Investigation of Horizontally Framed Miter Gates (CMITER)	Dec 1987
Technical Report ITL-87-8	Procedure for Static Analysis of Gravity Dams Using the Finite Element Method – Phase 1a	Jan 1988
Instruction Report ITL-88-1	User's Guide: Computer Program for Analysis of Planar Grid Structures (CGRID)	Feb 1988
Technical Report ITL-88-1	Development of Design Formulas for Ribbed Mat Foundations on Expansive Soils	Apr 1988
Technical Report ITL-88-2	User's Guide: Pile Group Graphics Display (CPGG) Post-processor to CPGA Program	Apr 1988
Instruction Report ITL-88-2	User's Guide for Design and Investigation of Horizontally Framed Miter Gates (CMITER)	Jun 1988
Instruction Report ITL-88-4	User's Guide for Revised Computer Program to Calculate Shear, Moment, and Thrust (CSMT)	Sep 1988
Instruction Report GL-87-1	User's Guide: UTEXAS2 Slope-Stability Package; Volume II, Theory	Feb 1989
Technical Report ITL-89-3	User's Guide: Pile Group Analysis (CPGA) Computer Group	Jul 1989
Technical Report ITL-89-4	CBASIN–Structural Design of Saint Anthony Falls Stilling Basins According to Corps of Engineers Criteria for Hydraulic Structures; Computer Program X0098	Aug 1989

(Continued)

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

(Continued)

	Title	Date
Technical Report ITL-89-5	CCHAN–Structural Design of Rectangular Channels According to Corps of Engineers Criteria for Hydraulic Structures; Computer Program X0097	Aug 1989
Technical Report ITL-89-6	The Response-Spectrum Dynamic Analysis of Gravity Dams Using the Finite Element Method; Phase II	Aug 1989
Contract Report ITL-89-1	State of the Art on Expert Systems Applications in Design, Construction, and Maintenance of Structures	Sep 1989
Instruction Report ITL-90-1	User's Guide: Computer Program for Design and Analysis of Sheet Pile Walls by Classical Methods (CWALSHT)	Feb 1990
Technical Report ITL-90-3	Investigation and Design of U-Frame Structures Using Program CUFRBC	May 1990
	Volume A: Program Criteria and Documentation	
	Volume B: User's Guide for Basins	
	Volume C: User's Guide for Channels	
Instruction Report ITL-90-6	User's Guide: Computer Program for Two-Dimensional Analysis of U-Frame or W-Frame Structures (CWFRAM)	Sep 1990
Instruction Report ITL-90-2	User's Guide: Pile Group–Concrete Pile Analysis Program (CPGC) Preprocessor to CPGA Program	Jun 1990
Technical Report ITL-91-3	Application of Finite Element, Grid Generation, and Scientific Visualization Techniques to 2-D and 3-D Seepage and Groundwater Modeling	Sep 1990
Instruction Report ITL-91-1	User's Guide: Computer Program for Design and Analysis of Sheet-Pile Walls by Classical Methods (CWALSHT) Including Rowe's Moment Reduction	Oct 1991
Instruction Report ITL-87-2 (Revised)	User's Guide for Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-89	Mar 1992
Technical Report ITL-92-2	Finite Element Modeling of Welded Thick Plates for Bonneville Navigation Lock	May 1992
Technical Report ITL-92-4	Introduction to the Computation of Response Spectrum for Earthquake Loading	Jun 1992
Instruction Report ITL-92-3	Concept Design Example, Computer Aided Structural Modeling (CASM)	
	Report 1: Scheme A	Jun 1992
	Report 2: Scheme B	Jun 1992
	Report 3: Scheme C	Jun 1992
Instruction Report ITL-92-4	User's Guide: Computer-Aided Structural Modeling (CASM) -Version 3.00	Apr 1992
Instruction Report ITL-92-5	Tutorial Guide: Computer-Aided Structural Modeling (CASM) -Version 3.00	Apr 1992

(Continued)

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

(Continued)

	Title	Date
Contract Report ITL-92-1	Optimization of Steel Pile Foundations Using Optimality Criteria	Jun 1992
Technical Report ITL-92-7	Refined Stress Analysis of Melvin Price Locks and Dam	Sep 1992
Contract Report ITL-92-2	Knowledge-Based Expert System for Selection and Design of Retaining Structures	Sep 1992
Contract Report ITL-92-3	Evaluation of Thermal and Incremental Construction Effects for Monoliths AL-3 and AL-5 of the Melvin Price Locks and Dam	Sep 1992
Instruction Report GL-87-1	User's Guide: UTEXAS3 Slope-Stability Package; Volume IV, User's Manual	Nov 1992
Technical Report ITL-92-11	The Seismic Design of Waterfront Retaining Structures	Nov 1992
Technical Report ITL-92-12	Computer-Aided, Field-Verified Structural Evaluation	
	Report 1: Development of Computer Modeling Techniques for Miter Lock Gates	Nov 1992
	Report 2: Field Test and Analysis Correlation at John Hollis Bankhead Lock and Dam	Dec 1992
	Report 3: Field Test and Analysis Correlation of a Vertically Framed Miter Gate at Emsworth Lock and Dam	Dec 1993
Instruction Report GL-87-1	User's Guide: UTEXAS3 Slope-Stability Package; Volume III, Example Problems	Dec 1992
Technical Report ITL-93-1	Theoretical Manual for Analysis of Arch Dams	Jul 1993
Technical Report ITL-93-2	Steel Structures for Civil Works, General Considerations for Design and Rehabilitation	Aug 1993
Technical Report ITL-93-3	Soil-Structure Interaction Study of Red River Lock and Dam No. 1 Subjected to Sediment Loading	Sep 1993
Instruction Report ITL-93-3	User's Manual—ADAP, Graphics-Based Dam Analysis Program	Aug 1993
Instruction Report ITL-93-4	Load and Resistance Factor Design for Steel Miter Gates	Oct 1993
Technical Report ITL-94-2	User's Guide for the Incremental Construction, Soil-Structure Interaction Program SOILSTRUCT with Far-Field Boundary Elements	Mar 1994
Instruction Report ITL-94-1	Tutorial Guide: Computer-Aided Structural Modeling (CASM); Version 5.00	Apr 1994
Instruction Report ITL-94-2	User's Guide: Computer-Aided Structural Modeling (CASM); Version 5.00	Apr 1994
Technical Report ITL-94-4	Dynamics of Intake Towers and Other MDOF Structures Under Earthquake Loads: A Computer-Aided Approach	Jul 1994
Technical Report ITL-94-5	Procedure for Static Analysis of Gravity Dams Including Foundation Effects Using the Finite Element Method – Phase 1B	Jul 1994

(Continued)

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

(Concluded)

	Title	Date
Instruction Report ITL-94-5	User's Guide: Computer Program for Winkler Soil-Structure Interaction Analysis of Sheet-Pile Walls (CWALSSI)	Nov 1994
Instruction Report ITL-94-6	User's Guide: Computer Program for Analysis of Beam-Column Structures with Nonlinear Supports (CBEAMC)	Nov 1994
Instruction Report ITL-94-7	User's Guide to CTWALL – A Microcomputer Program for the Analysis of Retaining and Flood Walls	Dec 1994
Contract Report ITL-95-1	Comparison of Barge Impact Experimental and Finite Element Results for the Lower Miter Gate of Lock and Dam 26	Jun 1995
Technical Report ITL-95-5	Soil-Structure Interaction Parameters for Structured/Cemented Silts	Aug 1995
Instruction Report ITL-95-1	User's Guide: Computer Program for the Design and Investigation of Horizontally Framed Miter Gates Using the Load and Resistance Factor Criteria (CMITER-LRFD)	Aug 1995
Technical Report ITL-95-8	Constitutive Modeling of Concrete for Massive Concrete Structures, A Simplified Overview	Sep 1995
Instruction Report ITL-96-1	User's Guide: Computer Program for Two-Dimensional Dynamic Analysis of U-Frame or W-Frame Structures (CDWFRM)	Jun 1996
Instruction Report ITL-96-	Computer-Aided Structural Modeling (CASM), Version 6.00 Report 1: Tutorial Guide Report 2: User's Guide Report 3: Scheme A Report 4: Scheme B Report 5: Scheme C	Apr 1996
Instruction Report ITL-96-	User's Guide: Computer Program for the Design and Investigation of Horizontally Framed Miter Gates Using the Load and Resistance Factor Criteria (CMITERW-LRFD) Windows Version	Jul 1996